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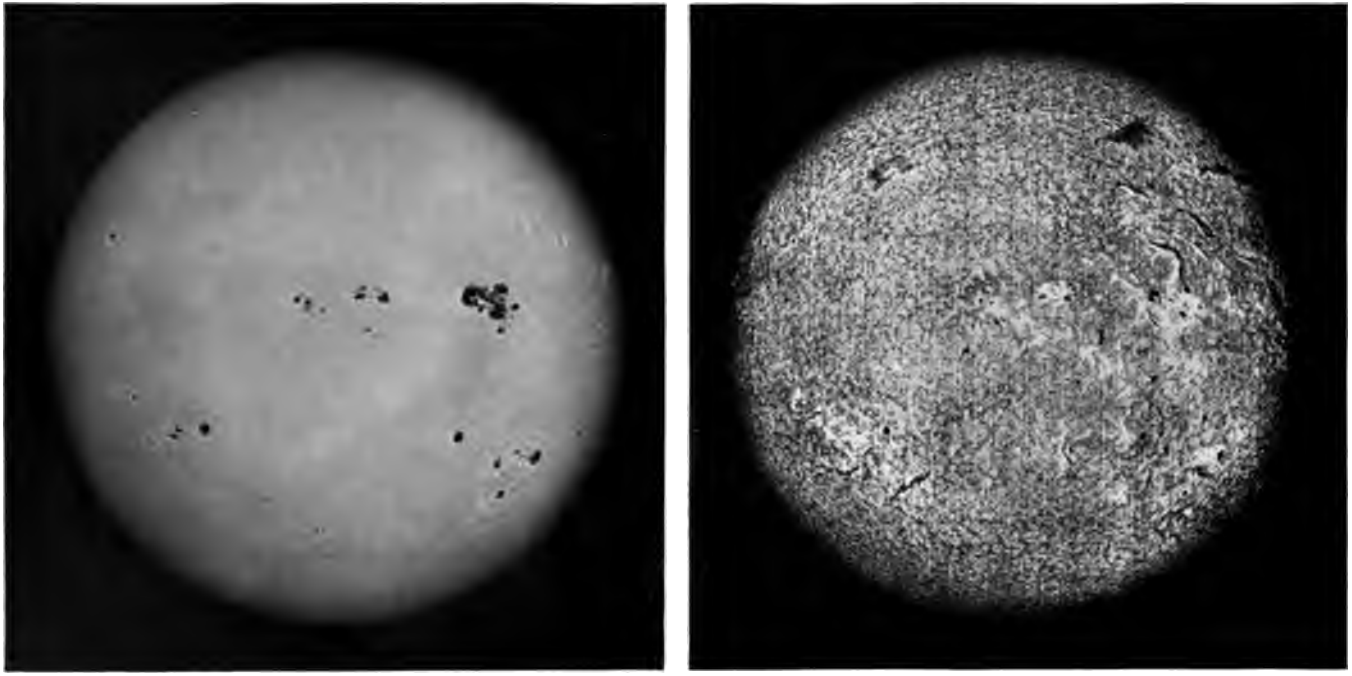

Photoheliogram and hydrogen (Hα) Spectroheliogram of the Sun, made on August 12, 1917.

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SOLAR RESEARCH AT THE MOUNT WILSON OBSERVATORY

By Ferdinand Ellerman

The activity of the Sun during the present sun-spot period, which reached its maximum about August, 1917, has offered many opportunities for observing and recording exceptional phenomena in the regions occupied by sun-spots. Some of the observations have been made and recorded visually, but the majority are photographic.

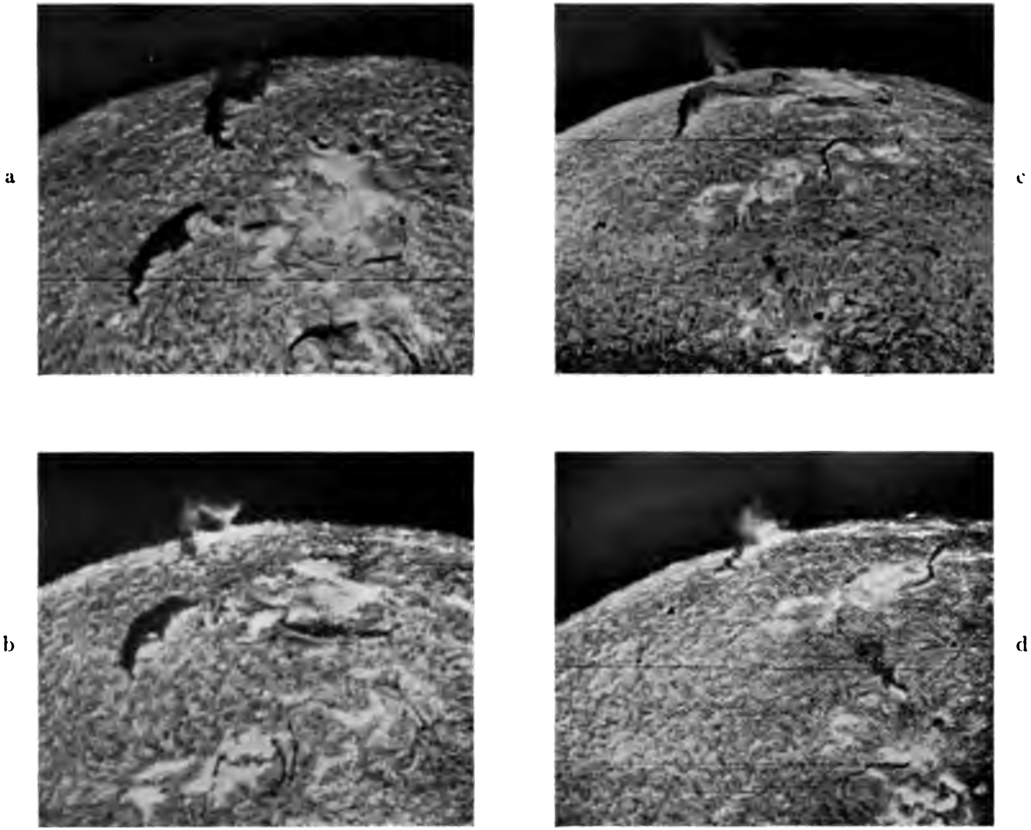
The instruments employed in the solar work during the last three years are the two tower telescopes. The Snow horizontal telescope has been dismantled and remodeled, but owing to the activities of our instrument shops in turning out war work for the government during the past two years the completion of the changes in the spectroscopic equipment for this telescope has been temporarily deferred.

THE 60-FOOT TOWER TELESCOPE

The 5-foot spectroheliograph, which had been used in the Snow telescope since October, 1905, was transferred to the 60-foot tower telescope in December, 1915, where it is used to record the Hα hydrogen flocculi on the 6.5-inch solar image formed by the 60-foot objective. It is mounted on beams overhead, in the observing room, and by means of a countershaft it is driven across the Sun's image by a variable speed motor, which also drives the 13-foot spectroheliograph described below. By rolling into place a diagonal mirror mounted on a carriage which runs on rails above the 13-foot spectroheliograph, the Sun's image is reflected on to the slit of the 5-foot spectroheliograph.

A grating having a very brilliant first-order spectrum is used for the dispersion. The light from the slit, after passing thru the collimating lens, is reflected by two plane mirrors on to the grating, which is turned so that the normal reflection is thrown beyond the camera lens. This makes the angle of incidence very large, resulting in a magnification of the spectrum scale, so that at Hα 1^{mm} equals about 4.5 A, which is more than twice the normal scale of dispersion and is sufficient to isolate the line from the continuous spectrum by means of the second slit.

PLATE II



Western part of the Sun photographed on (a) June 27, (b) June 28, (c) June 29, and (d) June 30, 1917, illustrating how dark hydrogen prominences projected on the disk become bright prominences at the limb of the Sun.

The small angular aperture, however, combined with the slowness of red sensitive plates of strong contrast, would make the exposure time prohibitive in making a run across the 6.5-inch image were the center of the line employed. The slit is therefore opened to include the entire line and its edges. This is sufficient to show the general distribution of the hydrogen flocculi, both bright and dark, over the Sun's surface, the lower level structure, and also the main features of the higher levels, including prominences projected on the disk. The width of the first slit is 0.15^{mm}, and that of the second is 0.20^{mm}, and the time of exposure-run about 20 minutes.

All the other photographs of flocculi and prominences are made with the 13-foot spectroheliograph. This instrument consists of a heavy box made of 12-inch channel iron, running horizontally on four large steel ball bearings, and moved across the Sun's image by means of a screw, driven by the variable speed motor and countershaft mentioned above, and a worm gear reduction. On the top of the box are mounted the first slit and two second slits, A and B. On the under side, extending into the 30-foot well, is an angle-iron frame, carrying the platform on which are mounted both the casting supporting the 13-foot collimator and camera lenses and mirror, and the casting for the grating support. The grating is similar to the one in the 5-foot spectroheliograph, and with the 13-foot focus lens gives a dispersion of 3.5 A per mm. at Hα. With this instrument, which has been in use since July, 1915, about 4500 plates have been made.

The slit widths employed for the spectroheliograms of the Sun's disk are 0.10^{mm} for the first slit, and 0.15^{mm} for the second when using the Hα or K2 line. When photographing the prominences, both the first and second slits are opened to 0.40^{mm} to admit sufficient light. Two second slits are employed when the surface of the Sun is being photographed. One is set on the center of the spectrum line used and the other on the continuous spectrum, thereby obtaining two simultaneous images on the plate, one showing the flocculi and the other the spots as in a direct photoheliogram. This gives a means of direct comparison without distortion between the two images.

Two objectives are employed, one a 12-inch visual of sixty feet focal length, the other a 4-inch photographic of eighteen feet focus. The latter gives a 2-inch image of the Sun.

As mentioned above, the larger image is used for the work with the 5-foot spectroheliograph for daily photoheliograms, and with the 13-foot for detail work on the Sun's surface and prominences. The 2-inch image is used to record the general distribution of the hydrogen and calcium flocculi and the prominences. Two exposures are usually made on each plate when the small image is used, varying the speed so as to get a duplicate record with different density.

The plates used are Wratten M for exposures with Hα, Seed 23 for K calcium prominences, and Seed Process O for K_2 calcium flocculi and for photoheliograms.

In using the 60-foot visual objective for photoheliograms, the aperture is reduced to 2.5 inches, thereby increasing the depth of focus. On account of the form of the color curve, the plate is placed about four inches beyond the visual focus. The plates obtained in this way seem fully as good as if a photographic objective were employed.

In Plate I is shown a photoheliogram made on August 12, 1917, and also for comparison a spectroheliogram made with the 5-foot spectroheliograph, using the Hα line. It is interesting to note the considerable amount of bright hydrogen structure around the spots, covering a large part of their area and giving an entirely different appearance from that of the direct image. The large dark patches are prominences seen in projection on the disk, and record themselves by the increase in absorption of the Hα line as the slit passes across them. The bright areas likewise show a reversal or brightening of the line over these regions. In some extreme cases the reversal of Hα is much brighter than the adjacent continuous spectrum.

When in 1903 at the Yerkes Observatory we first began using the hydrogen line Hβ for spectroheliograms, we found these large dark areas on our plates, and, assuming that they were prominences seen in projection on the disk, we called them such. The objection was raised by some observers that these were not prominences seen in projection, but another phenomenon which they called filaments. Subsequently, with the 5-foot spectroheliograph in the Snow telescope, in 1908, and, especially, later with the 13-foot spectroheliograph, we showed beyond question the true nature of the objects. If there is any doubt in the mind of anyone as to the dark patches being prominences projected on the disk, he will need only to study Plate II, which shows the western part of the Sun on June 27, 28, 29 and 30, 1917, taken with the center of the Hα line. This illustrates how these dark patches become prominences at the limb as they are carried over by the solar rotation.

THE 150-FOOT TOWER TELESCOPE

The 150-foot tower telescope has been used entirely for spectroscopic work, both visual and photographic. The 75-foot spectrograph top was originally designed so that it could be used as a spectroheliograph, but it was found by experience that the exposure time was prohibitive because of the small angular aperture (1 to 150). The instrument has therefore been employed on the class of work for which it is so eminently suited, i. e., large scale spectra for determining (a) the existence of the general magnetic field of the Sun as well as the localized magnetic regions around sun-spots, (b) solar rotation by means of the displacement of the spectral lines, (c) motions of the vapors in sun-spots, and various other kinds of work where a large solar image and high dispersion are essential.

The earlier work was in a large measure experimental, but regular lines of work were soon determined upon. One especially, that of studying the magnetic field in sun-spots, was of prime importance, and has been prosecuted continuously since the completion of the instrument.

The daily observations begin by orienting the spectrograph top to correspond with that of the solar disk. This is projected on a screen, which has a circle with meridians and parallels of latitude marked corresponding to the date of observation, in order to determine the latitude and longitude of the sun-spots. Near the edge of the screen where the latitudes 0°, 10° and 20°, north and south, cut the circle, pin holes are punched thru the card, and the light passing thru these falls on to a paper pad 10 x 20 inches in size about four inches below. Pencil marks are made where these light patches strike and also one at the center of the disk; the screen is then swung to one side and a circle described on the paper pad corresponding to the Sun's disk. The spots are now sketched carefully, and their latitudes and longitudes noted on the sketch. The paper pad is then removed and the analyzer placed over the slit.

The analyzer consists of a long Nicol prism, with normal surfaces, built up of four sections each about 33^{mm} long, 10^{mm} wide, and 18^{mm} thick. This is mounted about one-fourth inch above the slit. Above the Nicol, between two strips of plane parallel glass, are mounted strips of mica 2^{mm} wide with their axes inclined $+45°$ or $-45°$ to the length of the glass, alternating in adjacent strips for the entire length. This device is called a compound quarter-wave plate, and when circularly polarized light passes thru the mica, it is changed to plane polarized light (due to the retardation by a quarter of a wave) and is transmitted by the Nicol prism if the vibrations are parallel to the length of the prism, or extinguished if at right angles to it.

When a spot near the center of the Sun is examined we find certain lines in the spectrum widened, and others resolved into two or three components. This effect is due to the magnetic field produced by the ionized particles that emit the light, whirling in a vortex[1] and producing the same effect as an electric current flowing in a coil of wire, which is a magnet.

When a source of light between the poles of a magnet is examined with a spectroscope, most of the spectrum lines are seen to be broken up into three or more components. If examined along the lines of force, the side components are found to be circularly polarized with opposite sign, e. g., red component +, violet component −, or vice versa; and if a compound quarter-wave plate, as described above, is used, we see the red and violet components thru alternate strips.

Now if we examine the spectrum of the spot referred to above by passing the light thru the analyzer, we will see certain of the lines in the spectrum zigzagging on alternate strips, showing the presence of circularly polarized light in sun-spots. Some lines are affected much more than others, and the iron line at λ 6173.553 is especially suited to the examination and measurement of magnetic field strength.

This separation of the components of the lines is measured by means of a parallel plate micrometer. The micrometer consists of a piece of one-eighth-inch plate glass mounted so that it can be rotated about an axis lying in its plane, and at right angles to the edge, which is placed so that it falls on or touches the image of the

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[1] See Hale's "Notes on Solar Magnetic Fields and Related Phenomena," *these Publications*, **22**, 63, 1910.

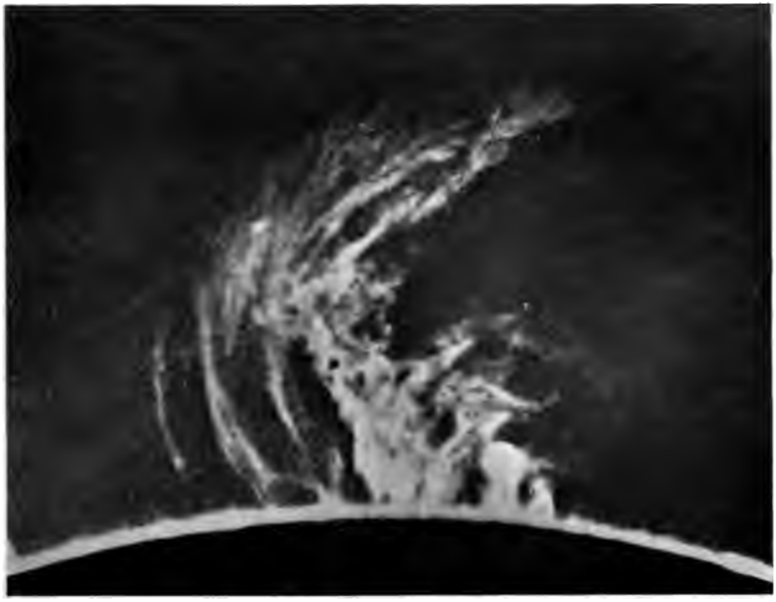

FIG. 1. Active prominence 140,000 miles high, photographed with the K line of calcium on July 9, 1917.

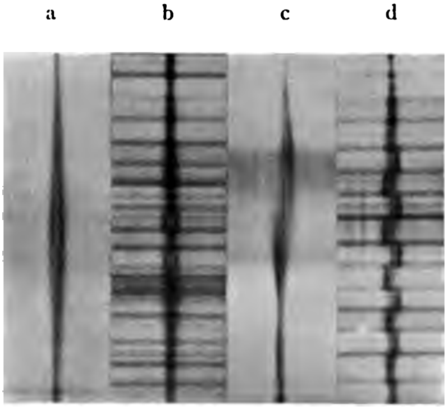

FIG. 2. Iron triplet λ 6173.553 in spectra of sun-spots. a and b, plane polarized light of spot near the Sun's limb, taken with Nicol and (a = single, b = compound) half-wave plate; c and d, circularly polarized light of spot near center of the Sun, taken with Nicol and (c = single, d = compound) quarter-wave plate; c shows reversal of sign of charge of two adjacent umbrae of large spot group of August, 1917.

junction between two mica strips, as seen in the spectrum by means of a low-power lens mounted above the plate glass. The glass is turned thru an angle sufficient to bring the component of the line viewed thru the glass into coincidence with the component on the adjacent strip, and a notation is then made on the spot sketch of the reading of the angle, recording also whether the red or the violet component of the line is transmitted by a certain marked strip, which is always used for reference. The field strength is obtained by means of a conversion curve or table.

When light from a source in a magnetic field is viewed across the lines of force, the components of the line are plane polarized, the light emitting the side components vibrating in a direction inclined 90° to that of the light giving the middle component. In this case the quarter-wave plate used as above for circularly polarized light must be supplanted by a half-wave plate. This is done by placing a single strip of quarter-wave mica over the compound quarter-wave plate, in such a way that the light transmitted is plane polarized parallel to and at right angles to the Nicol prism. If we now examine a triplet with this combination we will see alternately the side and central components of the line.

When the sun-spot near the edge of the Sun is examined we are receiving the light across the lines of force and the light is plane polarized, and if a triplet is examined with the compound half-wave plate and Nicol prism, the appearance of the spectrum line is similar to that of an ordinary link chain, the side and middle components alternating on the mica strips.

In Plate III, Fig. 2, is illustrated the appearance of the iron line λ 6173.553 under four different conditions. In each case the Nicol prism is used, and from a spot near the Sun's limb plane polarized light is received and examined in (a) with a single half-wave plate and in (b) with a compound half-wave plate. (c) and (d) are of spots near the Sun's center, giving circularly polarized light, (c) with single quarter-wave plate and (d) with compound quarter-wave plate. In (c), two umbrae of the great spot group of August, 1917, had opposite signs of charge and caused the side components of the line to alternate from one side to the other as one follows the length of the line. If the spots had been of the same sign or polarity, the side components would have remained on one side of the middle component.

The field strength of a spot varies approximately in proportion to the size of the umbra, and regardless of the size of the group. Average spots range from 2000 to 2700 gausses, while some of the largest have shown as high as 4000 gausses when using the iron line λ 6173.553 which for 10,000 gausses gives a separation of 0.84 A.

Photographic records are made of portions of the spectra of the larger spots and all the lines are subsequently measured. Spectra made with the compound quarter-wave plate and Nicol prism have been secured of a number of large spots, suitable for preparing a map of the sun-spot spectrum, from λ 3800 to λ 6600. The region λ 6000 to λ 6450 is complete, and it is hoped the remainder can be prepared during the present winter. The scale of the map is 10^{mm} per A, and 50 A per sheet, with a few units of overlap.

The general magnetic field of the Sun has received a large amount of attention and preliminary results were published[1] in 1913. During the summer of 1914 a series of daily spectra, covering several months with hardly an interruption, were secured from which material a thoro investigation has been made and a discussion of some of the results published in the *Astrophysical Journal*, **47**, 206, 1918. The observed latitude of maximum displacement is very close to the theoretical latitude of 45°, north and south, and varies with different elements and lines, which in a way represent levels. The values range from 10 to 60 gausses. There appears to be an inclination of the magnetic axis to the axis of rotation of several degrees, and a rotation period of about thirty-two days is indicated by the results. The obtaining of further material will have to be deferred until the spot period approaches the minimum, so as to avoid the local disturbing influence of sun-spot regions.

The motions of the vapors of various elements in the spots have been studied and results published by St. John.[2] He shows that the vapors of iron and heavier elements are flowing outward from the spots; aluminum lines, some magnesium lines, and calcium λ4227 are produced near the level of inversion, and Hδ, D1 D2, magnesium b1 b2, Hγ, H2 K2, Hα, and H3 K3 show increasing velocities towards the spots in the order mentioned.

The study of the solar rotation by means of spectral line displacement is still in progress, and some interesting facts are coming out of it. The rotation period as determined from different lines, varies, not only for different elements, but also for different lines of the same element, indicating a different period for different levels. See St. John, in the December number of this journal.

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[1] Hale, *Astrophysical Journal*, **38**, 27, 1913.
[2] St. John, *Astrophysical Journal*, **38**, 341, 1913.

The spectra for determining solar rotation are made by bringing the light from opposite limbs of the Sun on to the slit of the spectrograph by means of prisms. Over the slit are mounted three prisms, two receiving light from one limb, and the third, placed between the first two, receiving light from the opposite limb. Two auxiliary prisms mounted on slides bring the light from the Sun's edge to the prisms over the slit. Three narrow spectra are thus obtained close together on a single plate. Two sections of such a plate are reproduced in the February, 1918, number of this journal; they show very well the displacement of the solar lines in the middle spectrum towards the violet, compared with the top and bottom, indicating an approaching source, and therefore representing the light from the east limb. Note also the non-shifting of the lines of the great B group, which are of terrestrial atmospheric origin.

When conditions of good definition and other work permit, visual observations of the hydrogen Hα line are made around active sun-spot groups, for observing the distortions due to radial velocity, and for reversals of the line over the bright hydrogen regions. When unusual phenomena present themselves, photographic records are made. In the region of the great sun-spot group of August, 1917, distortions of the Hα line, indicating a falling back toward the Sun of 150$^{\text{km}}$ per second, were recorded, and, when the group was at the limb, the chromosphere was greatly disturbed and many interesting photographs of Hα were secured. It is hoped that some of these may be shown in a later note.

It was while observing the Hα line over a spot group in September, 1915, that a phenomenon[1] was discovered by the writer which had previously escaped our attention. Around the edge of the penumbra or between spots in an active group, there are frequently very small areas where the Hα line shows a bright band running at right angles to the line, extending usually 4 or 5 A on each side, lasting for a few minutes only, and then rapidly fading away. Sometimes several of these phenomena follow one another at intervals varying from a few minutes to half an hour. They occur only around active groups and are no doubt of an eruptive character, but deep seated, probably below or in the photosphere, as there is no effect on the absorption line, as would happen if the phenomena originated at the level of the bright structure which the hydrogen spectroheliograms show.

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[1] Ellerman, *Astrophysical Journal*, **46**, 298, 1917.

The very diminutive size, combined with the sudden appearance and disappearance, has suggested the name of hydrogen bombs. The phenomenon is visible only in the hydrogen lines. The Hβ line shows it to a less pronounced degree than Hα, and in Hγ only a feeble band is seen. No other lines in the spectrum seem to be affected.

The foregoing account outlines in brief some of the solar researches in progress at this observatory at the present time.

THE COLOR CURVE OF THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY

By Edith E. Cummings and Priscilla Fairfield

In planning for a new spectrograph for the 12-inch refractor of the Lick Observatory, the first question was whether a correcting lens would be required. To decide this the color curve of the object glass must be known.

Accordingly a 1-prism spectrograph was assembled, adjusted and attached to the telescope. The spectrograph consists of two square wooden tubes, the larger one attached to the telescope, the smaller one sliding within this and bearing all the optical parts. The motion of this tube is effected by a rack and pinion; the amount of motion is gauged by a millimeter scale on the side of the tube. The slit mechanism is of the simplest form, consisting merely of two polished metal plates whose distance apart is varied by a double-motion screw. A window in the outer tube permits access to the slit. The collimator and camera lenses are of 2.0 inches and 2.06 inches aperture respectively, and their focal lengths are 32 inches and 12.4 inches. The collimator lens is corrected for Hγ; the camera, for Hδ. The prism has a refracting angle of 60°; it is set for minimum deviation at Hγ. The collimator tube and prism box are entirely of wood, and the camera tube is of brass. The frame into which the plate-holder slides can be tilted several degrees with respect to the axis of the camera.

We made observations of the color curve in two different ways—photographically by Vogel's method and visually by the Foucault method. These were employed during the same period and as far as possible on the same nights. The observations were taken at temperatures ranging from $+0^\circ.6$ to $+17^\circ.8$ C.

Vogel's method consists in opening the slit wide and using the star-image, instead of the slit, as the source, the photographic plate having first been put accurately in the conjugate "dust-line" focus of the collimator and camera lenses. For a given position of the slit only one region (or sometimes two) of the spectrum will be in focus on the plate. The resulting image will be a spindle-shaped figure, the nodes of which travel along the spectrum as the slit is moved up and down in the axis of the telescope.

Our first step was to take a series of sky plates with the slit narrowed until the dust-lines showed prominently. By varying the camera focal settings and the tilt of the plate-holder we found for each region of the spectrum the position of the plate where the slit, as shown by the dust-lines, was in focus. We found that the entire range of the spectrum from 3600 to 6800 angstroms could be put in the dust-line focus with only three changes in the position of the plate. These positions are:

for 3600—4308 A, camera setting $8^{mm}.8$, plate inclined 4° to the axis of the camera, the shorter wave-lengths having the longer focus;
4308—4861 A, camera setting $8^{mm}.8$, plate perpendicular to the axis of the camera;
4861—6800 A, camera setting $8^{mm}.0$, plate inclined 4° to the axis of the camera, the longer wave-lengths having the longer focus.

To record this last region we stained plates by the Wallace formula.[1]

The plate-holder used was so constructed that the plate could be moved laterally by means of an external screw; thus as many as ten exposures could be taken on a ⅞ by 3¼ inch plate. Our practice was to start with small scale readings, and to move the spectrograph down by intervals of 1 or 2^{mm} for the successive exposures. The exposures were started and stopped by means of a piece of cardboard interposed above the slit. Correct timing required much practice. With the bright stars used (*Vega*, *Rigel* and *Sirius*) a few seconds or sometimes a fraction of a second was sufficient to give the requisite density. The time had to be varied according to the particular portion of the spectrum, the ends requiring six to eight times as long as the central portion (4500 A). In case the plate received too short or too long an exposure the position of the node was not clearly defined. Care had to be taken lest a region of low sensitiveness be mistaken for a node. Since the position of these false nodes did not vary with changing collimator settings, the measurer, after a little practice, was able to detect them at once. We rejected all images which were not of the right intensity or too broad on account of poor seeing. On six different nights, from October 30 to December 11, 1918, we took plates, twenty-seven of which were finally used. The prominent hydrogen lines in the stars used furnished the dispersion curve from which the wave-lengths of the nodes were determined. From 3750 to 5000 A the nodes are well defined and easy to measure. Tho slightly different methods of measurement and reduction were employed by the two observers, our resulting photographic curves are practically identical. For wave-lengths longer than 5000 A the color curve is so flat that the method is no longer applicable, and we were forced to reject all plates of this region.

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[1] *Lick Obs. Bull.*, **5**, 151, 1909.

In the Foucault method the observer views the camera lens thru a small hole in a card placed in the focal plane of the lens. Thus only a very limited portion of the spectrum can be seen at one time. By flexing the telescope the observer moves the star image until it is cut off by one of the slit jaws, which thus acts as a knife-edge; as he views the camera lens he sees its illumination cut off from one side or the other. By moving the spectrograph up and down, the position is found where the slit is exactly at the focus of the large objective for the given wave-length. At this position the illumination of the lens is cut off instantly, or from both sides simultaneously.

We made a series of cards in each of which was a vertical slit about $\frac{1}{2}^{mm}$ wide. The positions of individual slits were different by about 1^{mm}; 16 of them gave points from 4100 to 6900 A at intervals of about 50 to 100 angstroms according to the part of the spectrum. On several nights we employed additional slits to get intermediate points. The cards were trimmed to fit the plate-holder frame, and care was taken to adjust them properly before making observations. To determine the mean wave-length of the light seen thru each slit, we observed the sky spectrum to find the particular slit thru which each of the Frauenhofer lines, G, b, E, D, C and B could be seen. These positions could be measured with ease to $0^{mm}.1$; from the resulting dispersion curve the wave-lengths admitted thru each slit of the series were read. To guard against a variation between day and night conditions we several times determined the wave-lengths on the Moon's spectrum, both before and after series of Foucault observations. We found that dispersion curves determined by day and by night could be used with equal degrees of accuracy.

TABLE I—NORMAL PLACES

Observer . . .	Cummings		Fairfield		Cgs. & Fd.		Cgs. & Fd.		Cummings		Fairfield		Cgs. & Fd.		Cgs. & Fd.	
Method	Visual		Visual		Visual		Phot.		Visual		Visual		Visual		Phot.	
Mean Temp.	4°.6		4°.6		4°.6		4°.6		13°.6		13°.6		13°.6		13°.6	
Av. No. Pts. in a Normal.	9		8		19		3		5		3		8		3	
Normal No.	Coll. mm	λ	Coll. mm	λ	Coll. mm	λ	Coll. mm	λ	Coll. mm	λ	Coll. mm	λ	Coll. mm	λ	Coll. mm	λ
1	23.2	4211	22.6	4160	22.9	4208	37.0	3855	26.5	4130	22.0	4182	25.2	4152	43.0	3760
2	21.7	4264	21.0	4227	21.2	4246	34.0	3920	23.2	4213	19.0	4295	21.8	4226	40.0	3795
3	20.0	4282	19.7	4256	19.9	4272	32.0	3960	19.9	4324	17.8	4342	19.0	4302	39.5	3835
4	19.2	4327	19.0	4295	19.1	4315	30.0	3990	18.0	4362	16.3	4391	18.1	4359	38.3	3853
5	18.0	4368	18.1	4306	18.3	4333	28.0	4055	17.5	4411	15.7	4492	17.0	4417	37.7	3873
6	17.0	4398	17.1	4355	17.3	4365	27.0	4085	15.9	4500	14.2	4549	15.3	4502	36.3	3880
7	16.2	4479	15.7	4396	16.4	4412	26.0	4110	13.8	4610	13.0	4582	13.5	4630	35.7	3900
8	15.1	4527	14.9	4462	15.3	4477	25.0	4140	12.6	4716	12.2	4681	12.2	4700	34.7	3918
9	14.1	4568	13.9	4518	14.5	4523	24.0	4170	11.1	4818	11.1	4770	10.9	4802	34.0	3940
10	13.1	4629	13.2	4569	13.6	4586	23.0	4205	10.5	4922	10.5	4844	10.4	4914	33.0	3946
11	12.8	4699	12.2	4654	12.7	4651	21.7	4247	9.2	5050	10.0	4902	9.2	5048	32.0	3973
12	11.8	4718	11.3	4697	11.7	4691	19.0	4308	8.8	5151	9.3	5052	8.6	5190	31.3	3997
13	11.4	4798	10.8	4764	11.6	4766	17.7	4313	8.2	5214	8.3	5213	8.1	5276	30.3	3993
14	10.5	4830	9.9	4881	10.6	4810	17.3	4287	8.0	5328	7.7	5353	7.8	5411	29.7	4017
15	10.0	4901	8.7	4910	9.8	4895	16.0	4320	7.9	5458	7.7	5533	7.8	5583	28.7	4042
16	9.1	4942	8.5	5044	9.0	4954	16.0	4360	7.9	5612	7.5	5757	7.9	5766	28.0	4077
17	8.8	5036	8.0	5168	8.7	5056	15.2	4375	8.1	5772	8.0	5963	8.1	5934	27.0	4097
18	8.4	5078	7.5	5228	8.2	5114	14.0	4422	8.1	5916	8.3	6180	8.4	6159	26.0	4097
19	8.4	5153	7.4	5340	7.7	5188	13.0	4433	8.4	6150	8.5	6364	8.9	6410	24.3	4150
20	8.1	5197	7.3	5427	7.5	5271	13.8	4442	9.0	6430	9.1	6500	8.8	6670	25.3	4157
21	7.4	5211	6.9	5520	7.3	5345	12.0	4507	8.8	6450					23.7	4200
22	7.5	5297	7.0	5634	7.2	5446	12.0	4560	9.0	6840					22.7	4227
23	7.1	5340	7.4	5790	7.0	5520	11.0	4590							22.0	4277
24	7.2	5410	7.6	5852	7.2	5657	9.7	4678							20.5	4285
25	7.5	5497	6.9	5945	7.1	5776	9.0	4760							18.5	4300
26	7.0	5555	7.7	5970	7.3	5886	8.5	4940							17.5	4340
27	7.1	5683	7.6	6133	7.5	5950									16.0	4405
28	7.1	5740	7.8	6225	7.8	6108									15.0	4435
29	7.4	5882	8.0	6350	7.9	6227									14.0	4485
30	7.3	5915	8.5	6500	8.4	6404									13.0	4580
31	7.7	6055	8.7	6641	8.7	6571									12.0	4670
32	7.8	6150													9.5	4800
33	8.0	6222														
34	8.6	6298														
35	8.3	6415														

In Table I we have collected all the data obtained. The columns "Coll." give the position of the slit in terms of the scale on the moving tube; for brevity we called this simply the "collimator setting." Collimator settings increase numerically as the spectroscope is moved down (away from the 12-inch objective); when the setting is 6^{mm} the slit is 16.48 inches from the base plate of the telescope. A comparison of the different curves in Table I reveals several facts:

1. Altho the range of temperatures is small there is evidence of a temperature coefficient. At 13°.6 the focal length of the objective is $0^{mm}.7$ longer (on the average) than at 4°.6. This is expressed by the equation

$$R = R_0 + 0^{mm}.08\,(t - 9^\circ.1)$$

where R is the position of focus at temperature t, and R_0 is the focus at 9°.1 C. R_0 can be read from Figure 1, which is made by combining with equal weights the four curves: Visual 4°.6, Visual 13°.6, Photographic 4°.6, and Photographic 13°.6.

TABLE II

λ	Mean Phot. Curves ΔF, 13°.6−4°.6	Mean Visual Curves 13°.6−4°.6	Mean ΔF
	mm.	mm.	mm.
3900	+ 1.1		+ 1.1
4000	0.7		0.7
4100	0.6		0.6
4200	0.8	0.0	0.4
4300	1.8	0.0	0.9
4400	1.7	+ 0.6	1.2
4500	1.6	0.5	1.0
4600	1.7	0.4	1.0
4700	1.5	0.4	1.0
4800	1.0	0.4	0.7
4900		0.5	0.5
5000		0.6	0.6
5100		0.8	0.8
5200		0.8	0.8
5300		0.8	0.8
5400		0.8	0.8
5500		0.8	0.8
5600		0.8	0.8
5700		0.8	0.8
5800		0.8	0.8
5900		0.7	0.7
6000		0.7	0.7
6100		0.6	0.6
6200		0.5	0.5
6300		0.4	0.4
6400		0.3	0.3
6500		0.3	0.3
		Mean	+ 0.7 mm.

We plan to take further measures next summer at high temperatures. Comparison with the data obtained this winter should give a better value of the temperature coefficient.

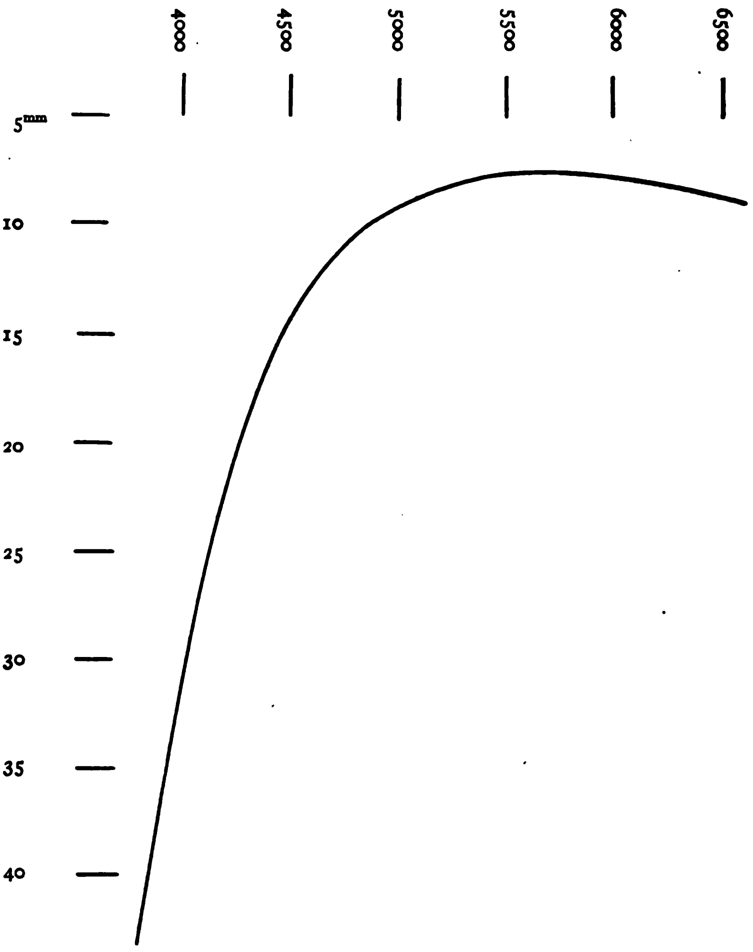

FIG. 1. Mean Color Curve at 9°.1 C.
12-inch Object Glass.

2. The visual measures show a personal equation between the two observers. Cummings's measures indicate a longer focal length than Fairfield's, the difference being a maximum for short wave-lengths.

TABLE III

	ΔF, Cummings — Fairfield		
λ	4°.6 mm.	13°.6 mm.	Mean ΔF mm.
4200	+ 1.6	+ 1.5	+ 1.6
4300	+ 1.2	+ 1.3	+ 1.2
4400	+ 1.4	+ 1.2	+ 1.3
4500	+ 1.4	+ 1.3	+ 1.4
4600	+ 1.2	+ 1.1	+ 1.2
4700	+ 1.0	+ 1.0	+ 1.0
4800	+ 0.7	+ 0.7	+ 0.7
4900	+ 0.6	+ 0.3	+ 0.4
5000	+ 0.3	0.0	+ 0.2
5100	+ 0.2	0.0	+ 0.1
5200	0.0	0.0	0.0
5300	0.0	+ 0.1	0.0
5400	0.0	+ 0.3	+ 0.2
5500	0.0	+ 0.4	+ 0.2
5600	0.0	+ 0.4	+ 0.2
5700	0.0	+ 0.4	+ 0.2
5800	0.0	+ 0.3	+ 0.2
5900	+ 0.1	+ 0.2	+ 0.2
6000	+ 0.2	+ 0.2	+ 0.2
6100	+ 0.2	0.0	+ 0.1
6200	+ 0.3	0.0	+ 0.2
6300	+ 0.3	0.0	+ 0.2
6400	+ 0.3	0.0	+ 0.2
6500	+ 0.3	0.0	+ 0.2

3. The visual and photographic curves differ in a peculiar manner which we are unable to explain. For wave-lengths 4400 to 4900 A the photographic method indicates a focal length about $1^{mm}.8$ shorter than that determined by the visual method.

TABLE IV

	ΔF, Photographic — Visual		
λ	4°.6 mm.	13°.6 mm.	Mean Diff.
4200	0.0	+ 1.0	+ 0.5
4300	− 1.5	0.0	− 0.8
4400	− 2.1	− 1.7	− 1.9
4500	− 2.4	− 1.6	− 2.0
4600	− 2.4	− 1.5	− 2.0
4700	− 2.3	− 1.0	− 1.6
4800	− 2.0	− 1.0	− 1.5
4900	− 1.6		− 1.6

It was thought possible that spherical aberration in the 12-inch objective might be accountable for the difference Visual *minus* Photographic. To test this we cut two diaphragms, one covering the central 5-inch zone of the lens, the other leaving only this portion clear. On seven different nights we determined the color curve by the Foucault method for one zone and then for the other.

A slight difference was found; rays from the central zone have about $0^{mm}.5$ longer focus than those from the outer zone. The mean differences from six pairs of curves for each observer are collected below.

TABLE V

ΔF, Outer Zone—Central Zone

λ	Mean Diff. mm.	λ	Mean Diff. mm.
4400	−0.2	5500	−0.6
4500	0.2	5600	0.6
4600	0.2	5700	0.6
4700	0.3	5800	0.6
4800	0.4	5900	0.6
4900	0.5	6000	0.6
5000	0.5	6100	0.7
5100	0.6	6200	0.6
5200	0.6	6300	0.6
5300	0.5	6400	0.6
5400	0.5		

Average $\Delta F = -0.5$ mm.

The individual measures for spherical aberration have been incorporated into the mean curves of Table I with weights proportional to the areas, i. e., weights 6, 5 and 1, respectively, for the full aperture, outer zone, and central zone. For the rays from the central zone the focus is much less definite than for the outer zone, an additional reason for giving those points small weight.

In order to find the relation between the collimator scale and the focal length of the telescope, we determined the position of the slit with respect to the optical center of the 12-inch objective. This was done by means of micrometer measures of the differences in declination between the following pairs of *Pleiades* stars:

TABLE VI

B.D.	Mag.		B.D.	Mag.	$\Delta\delta$
+23°557	4.0	and	+23°558	6.2	300".23
23°558	6.2	and	23°562	7.8	400 .81
23°561	7.5	and	23°562	7.8	470 .21
23°563	7.2	and	23°560	7.5	403 .87

The differences in declination are the results of Dr. Elkin's measures[1] with the Yale heliometer, reduced to 1910.0.

We took 44 sets of measures, 22 for each observer, by the method of double distances; a set consists of 3 to 6 measures wires direct and 3 to 6 measures wires reversed. Each set gives a determination of the angular value of one revolution of the screw, the mean result being

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[1] R. G. Aitken. *The Binary Stars*, page 46. N. Y. 1918.

$$R = 14''.031 \pm 0''.0014$$

The focal length of the telescope was computed from the formula

$$F = \frac{B}{2} \cot \frac{R}{2}$$

where F is the focal length, B is the pitch of the micrometer screw, and R the angular value of one revolution; the micrometer screw has eighty threads to the inch. For the "visual rays" the focal length of the telescope at $10^{\circ}.0$ C is 15 feet 3.8 inches ±0.018 inches.[1] Referring to Figure I and the temperature equation and assuming that the light which was in focus was of wave-lengths 5300 to 6100 A we find that when the collimator setting is 8^{mm} the slit is 15 feet 3.8 inches from the optical center of the 12-inch lens. Collimator setting 8^{mm} puts the slit 15 feet 4.7 inches from the outer surface of the objective. This indicates that the optical center of the lens is 0.9 inches behind the front surface.

The aperture of the objective is 12.00 inches, so that the ratio $F{:}A$ is 15.4. Since $F{:}A$ for the collimator lens is 16, it is evident that our spectroscope has not utilized the outer ¼ inch zone of the objective.

In conclusion we wish to express our thanks to Director Campbell for kindly placing all facilities at our disposal; and to the Director, Dr. Aitken, Dr. Moore and Dr. Paddock for generous advice and assistance.

January 14, 1919.

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[1] In computing the probable error of F we assumed the relation $\frac{F}{\epsilon_0} = \frac{14.031}{.0014}$

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1919

By Malcolm McNeill

PHASES OF THE MOON, PACIFIC TIME

New Moon....	Mar.	2,	$3^h\ 11^m$	A.M.	First Quarter...	April	7,	$4^h\ 39^m$	A.M.
First Quarter...	"	8,	7 14	P.M.	Full Moon.....	"	15,	12 25	A.M.
Full Moon.....	"	16,	7 41	A.M.	Last Quarter...	"	23,	3 21	A.M.
Last Quarter...	"	24,	12 34	P.M.	New Moon....	"	29,	9 30	P.M.
New Moon....	"	31,	1 5	P.M.					

The Sun passes the vernal equinox and spring begins at 8 A. M. March 21, Pacific Time.

Mercury passed superior conjunction with the Sun and became an evening star on February 23, but does not attain a sufficient distance for naked eye visibility until after the first week of March. It then sets about an hour after sunset and may be seen if weather conditions are very good. The interval does not fall below an hour during the rest of the month and at the time of greatest east elongation, March 21, it is about an hour and one-half. The March greatest east elongation is much smaller than the average since it occurs only a week after the planet passes perihelion. Conditions for visibility will be about as good at the next greatest east elongation occurring in July, altho the spring greatest east elongations are usually the best of the year for naked-eye observations. After passing elongation *Mercury* approaches the Sun quite rapidly, reaching conjunction and becoming a morning star on April 7. By the end of the month it has nearly reached greatest west elongation, and rises nearly an hour before sunrise. On March 11 *Mercury* is in conjunction with *Mars*, the latter planet passing about 1° to the south.

Venus remains an evening star, gradually drawing away from the Sun and setting later, on March 1 not quite two hours after sunset and on April 30 rather more than three hours. Altho by no means at its greatest brilliancy, which it will not reach until August, it is, after the Sun and Moon, easily the most conspicuous object in the sky. It moves during the two months not quite 60° northward and eastward from *Pisces*, thru *Aries*, into the western part of *Taurus*. About the middle of April it passes between the *Pleiades* and *Hyades* groups in *Taurus*.

Mars remains an evening star, setting thruout the two months' period at a few minutes after seven o'clock local mean time. The

Sun is, however, rapidly overtaking it in their common eastward motion and their apparent distance diminishes from about 15° on March 1 to only a little more than 2° on April 30, a distance far too small for naked-eye view of the planet; indeed it will be hardly possible to see *Mars* even on April 1 unless weather conditions are exceptionally favorable. Its actual distance from the Earth increases slightly and consequently there is a small loss of brightness, but it is scarcely noticeable. It moves about 43° eastward and 17° northward from *Pisces* into *Aries*, and on March 6 passes less than one degree south of the vernal equinox.

Jupiter is still in fine position for evening observation, remaining above the horizon until after 3 A. M. on March 1, and setting shortly before midnight on April 30. On March 2 it ceases to move westward and begins to move eastward among the stars of the constellation *Gemini*. The whole distance moved during the two months is about 6°, and at the close of the period it is a few degrees south and west of *Castor* and *Pollux*.

Saturn is also in fine position for evening observation, having passed opposition with the Sun on February 14. On March 1 it does not set until about 6 A. M., and on April 30 at about 2 A. M. It moves about 2° westward in the constellation *Leo* during the two months, away from *Regulus, Alpha Leonis*, the brightest star in the constellation, but its distance at the end of April is only about 4°. Its westward motion ceases on April 23.

Uranus is now a morning star, having passed conjunction with the Sun on February 17. On April 1 it rises not quite two hours before sunrise, but as it is only about as bright as the faintest stars visible to the naked eye, it will hardly be possible to see it until summer.

Neptune, too faint for naked-eye view, remains in the constellation *Cancer*. It is on the meridian at about 10 P. M. on March 1, and at about 6 P. M. on April 30.

THE ADOLFO STAHL LECTURES IN ASTRONOMY

Mr. Adolfo Stahl has generously made provision for the publication in book form of the two series of Adolfo Stahl Lectures in Astronomy, delivered in San Francisco in the seasons 1916-17 and 1917-18, under the auspices of the Astronomical Society of the Pacific. The book is now in press and will be ready for distribution at an early date.

The lectures have been revised by their authors and the twelve papers, comprising approximately 240 printed pages of the size of that on which this note appears, therefore represent our knowledge of the subjects treated at the close of the year 1918. Fifty-four full-page plates and twenty-four figures in the text serve as substitutes for the numerous lantern slides exhibited when the lectures were delivered. The book will be substantially bound in cloth, and the workmanship thruout will be of a high order.

The price of the volume, postage paid, has been fixed at $2.75, but it has been decided to offer the book to members and friends of the Society who send in their orders *in advance of publication* at the special price of $2.25, postage paid. Orders should be sent to the Secretary of the Society, Mr. D. S. Richardson, 128 Lick Building, 35 Montgomery Street, San Francisco, Calif. In accordance with the understanding with Mr. Stahl, the proceeds of the sale of the book will go to the Society, to form a special fund.

COMMITTEE ON PUBLICATION.

NOTES FROM PACIFIC COAST OBSERVATORIES

STARS WHOSE SPECTRA ARE COMPOSITE

In the progress of the work of the Henry Draper Memorial, Harvard Observatory had observed, up to 1913, that seventy-six stars[1] have composite spectra; that is, spectra containing in each case the principal characteristics of two distinct spectral types. Professor Pickering has interpreted the composite spectrum to mean that the stellar source is not the single star which it appears to be when viewed in a telescope, but that it consists of two stars so close together that they appear as a single star, and whose spectra are of quite different types. The resulting blended spectrum will show the leading features of both types more or less successfully, depending upon the relative brightness of the two components. The inference may safely be drawn that, in general, each such pair of stars is a binary system in which the two components revolve around their common center of mass. The spectrograph should detect variable radial velocities in these systems, if continued thru a sufficient period of time, and if the orbital motions are not in a plane at right angles to the observer's line of sight.

Of the 76 composites, 40 are brighter than visual magnitude 5.5, and 36 are fainter.

In the regular pursuit of the program of radial velocity determinations with the Mills spectrographs at Mount Hamilton and at Santiago, Chile, we have obtained several spectrograms of each of 37 of the brighter group of 40 composites, and one spectrogram of another star in the group; only two stars in the group of 40 remain unobserved. We have secured no spectrograms of the 36 composites fainter than 5.5 visual magnitude, and in fact we have no plans as to observing those stars.

The observations of the 37 stars have led to results which may be described as follows:

Twenty-three stars of the group have variable radial velocity.

For six stars the radial velocities seem to have varied thru small ranges, but the apparent variations may have resulted from the normal and unavoidable errors of observation. Future spectrograms will probably establish that some or all of the suspected variations are real.

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[1] To the lists of stars with composite spectra, as published in *Annals H. C. O.*, **28**, 92 and 229 and **56**, 113 and 160. and in *Harvard Observatory Circular*, No. **178**, are to be added five such stars mentioned in a letter received from Miss Cannon.

For eight stars the observed results have shown no appreciable variations.

If all of the thirty-seven stars are binary systems, as their composite spectra indicate, it is reasonable to expect that some of the periods of revolution are long, in which cases the spectrographic observations, made within short periods of time, would not be able to detect variations in their radial velocities. It is also to be expected that the orbital planes of some of the systems are nearly perpendicular to the observer's line of sight, and the spectrograph is powerless to detect motions within those systems. So far as our spectrographic observations are concerned, there is no reason to doubt that all of the thirty-seven stars are binary systems.

Four or five scores of the naked-eye stars have been found at various observatories to have two sets of lines in each of their recorded spectra, with the two sets essentially or nearly alike. The two sets of lines proceed from the two close components of binary systems, and the spectra are in fact composite, but in practice the term "composite" has been applied only to the combination of spectra of very different types.

W. W. CAMPBELL.

THE VARIABLE VELOCITY OF β CYGNI

The brighter component of the well-known double star *β Cygni* ($\alpha = 19^h\ 27^m$; $\delta = +27°\ 45'$) has been observed for radial velocity with the Mills spectrograph on twenty-five nights between 1898 and 1918 inclusive. There were indications in 1910-11 that the velocity varies slowly. The observations secured in 1917-18 converted the indications into certainty. The observed radial velocities are as grouped below, the subscripts indicating the number of individual results upon which the group velocities depend.

1898-01, $V_5 = -25.3$ km. sec.
1904-07, $V_2 = -24.4$
1910-12, $V_6 = -23.2$
1913-14, $V_6 = -23.0$
1917-18, $V_6 = -21.6$

The fainter component in the visual binary system is 35″ from the brighter component, in position angle 55°, and no appreciable change in the relative positions of the two components has been observed in the century or more covered by position observations.

The observed variation in the radial velocity of the brighter component is therefore not due to orbital motion in the visual system.

In *Annals Harvard Observatory*, **28**, Part 1, 98, 1897, the spectrum of the brighter component of *β Cygni* is described as "composite." It is in general of the type corresponding to yellow stars, such as *Arcturus* or *α Cassiopeiae*, but has also the strong hydrogen lines and the weak and narrow K calcium line characteristic of many blue stars, such as *Sirius*. The composite spectrum "could be explained on the supposition that the brighter member of the visual double star is itself double, one component being a star of the 'second type' (yellow), the other a star of the 'first type' (blue), approaching the second type." Our observed radial velocities are confirmatory of the Harvard hypothesis that *β Cygni* is a triple system. The period of revolution in the spectroscopic binary system comprised in the brighter component of the visual binary is apparently of considerable length, inasmuch as the radial velocity varies slowly and the variation observed in twenty years seems to have been in only one direction.

W. W. CAMPBELL.

AN INTERESTING DOUBLE STAR

In the course of the radial velocity program of this observatory, the star Boss 6158, R. A. $23^h 54^m.4$, Dec. + 33° 11′ (1900) was observed. This star is a double, No. 12675 Burnham's *General Catalogue*, the separation of the components being now in the neighborhood of 2″. They are of equal magnitude, visual 6.58, photographic 7.08 and of the same type about F5. Burnham plots their relative motion which he states is "apparently rectilinear."

It seemed to me, when they were so close together in the sky and of equal magnitude and type, there was a high probability that they were physically connected. If in addition their radial velocities proved to be nearly the same, this probability would be greatly strengthened.

It will be of interest as showing the actual performance of the new installation to give the particulars of observation and measurement. Spectra of each have been obtained on five nights with the single prism form of the spectrograph, linear dispersion 35A per mm. at Hγ. The spectra are all well exposed altho the average exposure time given each star of 7.08 photographic magnitude was 19.6

minutes. The plates were measured on the Hartmann Spectro-Comparator with the following values of the velocity:

Date. 1918	Velocity Preceding Star	Velocity Following Star
Oct. 19	−5.7	−5.8
" 24	−7.9	−3.0
" 29	−8.0	−3.5
Nov. 24	−6.5	−5.4
Dec. 15	−8.3	−3.3
Means	−7.4	−4.2

The probable error of a single plate so far as it means anything from so few observations is ±0.85km per second.

The difference in velocity is of the order to be expected if the star were a binary and this taken in conjunction with the small separation, the equality in magnitude and type make a chain of coincidences improbable on any supposition except that the stars are physically connected.

J. S. Plaskett.

Dominion Astrophysical Observatory,
Victoria, B. C., Jan. 15, 1919.

Fourteen Spectroscopic Binaries

Spectroscopic observations of the following stars made at Mount Wilson with the 60-inch reflector and the Cassegrain spectrograph show variations in the radial velocity.

TU *Cassiopeiae* $\alpha = 0^h\ 21^m$ $\delta = +50°\ 43'$ $m = 7.2 - 8.6$

This star is a Cepheid variable with a period of 2.14 days. Three observations show a range between −4 and −43km. The spectral type as based upon the hydrogen lines varies from F0 at maximum to F9 at minimum of light. As in the case of other Cepheids the remaining lines of the spectrum, with the exception of the enhanced lines, show little change.

Boss 373 = Σ 145 $\alpha = 1^h\ 37^m$ $\delta = +25°\ 14'$ $m = 6.3$

This is a most interesting binary, with the spectra of both components present. It is the brighter star of the visual binary. The maximum relative velocity observed among twelve spectrograms is 107km. The spectra of the two components are nearly the same, and are estimated as F5. The period of variation is about four days, and the orbit is now under investigation.

Boss 523 $\alpha = 2^h\ 32^m$ $\delta = +24°\ 23'$ $m = 6.0$

This is the brighter star of the visual binary Σ 5. A large number of spectrograms have been obtained and the computation of the orbit is nearly completed. The variation in velocity is from -10 to $+36^{km}$ in a period of 9.85 days. The spectrum of the star is F4.

o Σ 82 $\alpha=4^h\ 17^m$ $\delta=+14°\ 49'$ $m=7.0$

The brighter star of this visual binary is a spectroscopic binary. Four spectrograms show a range of 41^{km}. The spectral type is F8.

Boss 1131 $\alpha=4^h\ 43^m$ $\delta=+18°\ 33'$ $m=6.8$

Seven spectrograms show a range between $+41$ and $+70^{km}$. The spectral type is Go.

TT *Aurigae* $\alpha=5^h\ 3^m$ $\delta=+39°\ 28'$ $m=8.5-9.2$

This star is an Algol variable investigated photometrically by Joy, with a period of 1.33 days. Photographs of its spectrum show the presence of two components of nearly the same spectral type which is estimated as B5. The maximum relative velocity so far observed exceeds 450^{km}. The spectrum is very difficult of measurement, the lines due to the second component being especially faint and diffuse.

Boss 2285 $\alpha=8^h\ 31^m$ $\delta=+6°\ 58'$ $m=6.0$

Fourteen spectrograms of this star show a variation in velocity of from -3 to $+41^{km}$. The period is about 14 days, and the orbit is now under investigation. The spectral type is F8.

Boss 2447 = 75 *Cancri* $\alpha=9^h\ 3^m$ $\delta=+27°\ 3'$ $m=6.0$

Six spectrograms show a range in velocity of 32^{km}. The spectrum is of type G1.

S *Antliae* $\alpha=9^h\ 28^m$ $\delta=-28°\ 12'$ $m=6.3-6.8$

This star is classed in the catalogs as a Cepheid variable with a period of light variation of 0.3 day. Shapley has interpreted it, however, as a rotating ellipsoid (*A. N.* **194**, 353, 1913). The spectrum is extraordinarily difficult of measurement, being of type A6p with broad indistinct lines. There seems to be little doubt, however, of a variation in velocity of the order of 100^{km}. Six spectrograms have been secured, and on three of these the presence of a secondary spectrum is suspected. The spectral type of this star is entirely different from that of the normal Cepheid variables.

Lalande 29330 $\alpha=16^h\ 1^m$ $\delta=+10°\ 57'$ $m=8.5$

Eight photographs of the spectrum give velocities ranging between -21 and -94^{km}. The spectrum is of type Ko. The absolute magnitude of the star is about 6.7.

205 *Draconis* $\alpha = 18^h\ 45^m$ $\delta = +49°\ 19'$ $m = 7.2$

This star shows an interesting spectrum of double lines on three of the six photographs. The maximum observed relative velocity is 203^{km}. The two spectra are closely alike in type, being estimated as F2. The intensities of the lines in the two spectra are approximately in the ratio of 3 to 2.

Boss 5591 $\alpha = 21^h\ 40^m$ $\delta = +28°\ 19'$ $m = 6.9$

Five out of six spectrograms of this star show double lines with a maximum relative velocity of 195^{km}. The period of variation is probably a few days. The spectra of the two components are similar, being of type Fo, and the lines are of nearly equal intensity. This star is near μ *Cygni.*

Boss 5683 $\alpha = 22^h\ 2^m$ $\delta = +82°\ 23'$ $m = 7.5$

This star is the fainter component of the visual binary Σ 2873. Seven spectrograms have been measured, of which the last shows the presence of a faint secondary spectrum with a displacement of 175^{km} relative to that of the principal star. The lines of the primary spectrum show a variation in velocity of from $+43$ to -123^{km}. The spectrum of the principal star is G4p.

Lalande 46867 $\alpha = 23^h\ 50^m$ $\delta = +28°\ 5'$ $m = 7.0$

Six spectrograms of this star show a range of from $+27$ to -55^{km}. The spectral type is K2.

W. S. ADAMS
A. H. JOY

A VERY FAINT STAR OF SPECTRAL TYPE F

In the number of this journal for December, 1917, I announced the discovery of a faint star with a proper motion of $3''.01$ annually. Its position is

$$\alpha_{1900} = 0^h\ 43^m\ 52^s \qquad \delta_{1900} = +4°\ 55'$$

Mr. Seares later published photovisual and photographic magnitudes: 12.34 and 12.91, respectively. The spectrum was found to be Fo.

Sixteen plates have since been secured for the determination of parallax; the result is

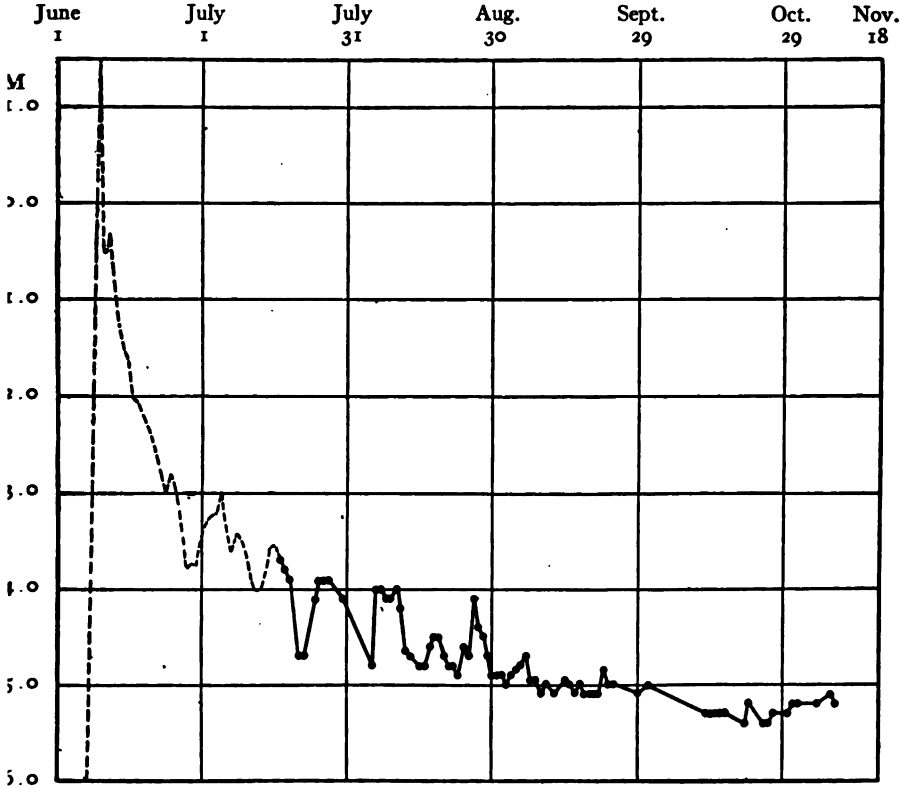
$$\pi_{rel.} = +0''.244 \pm 0''.008$$

This parallax gives for the absolute magnitude of the star, +14.3 photovisual and +14.8 photographic. It is, therefore, by far the faintest F-type star known at the present time.

A. van Maanen.

The Light Curve of Nova Aquilae No. 3

The following observations of the magnitude of *Nova Aquilae No. 3* were made visually on Mount Wilson, using the comparison stars listed in *Harvard Bulletin*, No. 661. Most of the estimates were made when the nova was near the zenith, and no correction has been applied for atmospheric extinction. In the diagram the light curve for dates earlier than July 17 is taken from *Harvard Circular*, No. 208. The observations on July 21 and July 22, which show a deep minimum, were confirmed by the estimates of other observers on Mount Wilson. On August 12, β *Scuti* was recorded as appearing brighter than magnitude 4.5.



The Light Curve of Nova Aquilae No. 3

Date	G.M.T.	Mag.	Remarks
July 17	$16^h 55^m$	3.7	Moonlight
18	17 0	3.8	“
19	17 0	3.9	“
21	17 20	4.7	“
22	16 40	4.7	“
24	17 15	4.1	“
25	17 25	3.9	“
26	16 40	3.9	
27	16 20	3.9	
30	17 30	4.1	
Aug. 5	17 20	4.8	
6	16 40	4.0	
7	16 30	4.0	
8	16 50	4.1	
9	16 30	4.1	
10	16 55	4.0	
11	17 10	4.2	
12	17 20	4.65	
13	16 50	4.7	Moonlight
15	16 25	4.8	“ ; thru fog
16	17 0	4.8	“
17	16 55	4.6	“
18	16 30	4.5	“
19	16 50	4.5	“
20	15 35	4.7	“
21	16 15	4.8	“
22	16 10	4.8	“
23	16 0	4.9	Sky covered with cirrus
24	16 10	4.6	
25	15 45	4.7	
26	15 45	4.1?	Thru clouds
27	15 30	4.4?	“
28	17 0	4.5	
29	16 55	4.7	
30	17 30	4.9	Scattered clouds
31	16 40	4.9	
Sept. 1	17 10	4.9	
2	16 50	5.0	
Sept. 3	$16^h 15^m$	4.9	
4	16 0	4.85	
5	16 15	4.8	
6	16 10	4.7	
7	16 0	4.95	
8	16 20	4.95	
9	16 20	5.1	
10	17 0	5.0	Some cirrus
12	15 40	5.1	Thru clouds
14	16 40	4.95	Moonlight
15	17 0	5.0	“
16	16 15	5.1	“
17	16 10	5.0	“
18	16 15	5.1	“
19	16 40	5.1	“
20	15 25	5.1	“
21	15 40	5.1	“ ;scattered clouds
22	15 30	4.85	
23	15 20	5.0	
24	15 30	5.0	
29	16 30	5.1	Thru clouds
Oct. 1	15 50	5.0	Scattered clouds
13	16 20	5.3	
14	15 10	5.3	Moonlight
15	15 10	5.3	“
16	15 0	5.3	“
17	14 50	5.3	“
21	15 10	5.4	
22	15 30	5.2	Thru clouds
25	15 10	5.4	
26	15 30	5.4	
27	15 25	5.3	
30	15 10	5.3	
31	16 5	5.2	
Nov. 1	16 10	5.2	
5	15 0	5.2	
8	15 10	5.1	
9	14 55	5.2	

MILTON HUMASON.

THE MOTION IN SOME A DOUBLE STARS

FOURTH NOTE

Three earlier notes[1] in these PUBLICATIONS have called attention to certain binary stars discovered in the Lick Observatory double-star survey which were shown to be in relatively rapid orbital motion by the measures made at a later epoch. The work of remeasuring the A double stars was continued during the year 1918 and many additional pairs were found in which the angular change since discovery was too great to be attributed to error of measure. The following list includes the more interesting of these pairs.

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[1] *Publ. A. S. P.*, **27**, 230, 1915; **28**, 276, 1916; **30**, 60, 1918.

Star	Δ Epoch	Δθ	ρ Disc.	Δθ	Mags.
A 207	16.7 yrs.	+31°.9	0″.24	+0″.02	9.7—9.8
A 222	16.2	−31 .7	0 .23	−0 .01	8.6—8.8
A 889	14.1	−46 .7	0 .24	−0 .03	9.4—10.0
A 893	13.9	−37 .4	0 .20	+0 .04	8.9—9.8
A 1095	12.9	+18 .7	0 .31	+0 .04	8.7—9.3
A 1109	13.0	+18 .4	0 .63	+0 .18	7.7—9.7
A 1404	11.7	−15 .8	0 .21	−0 .03	7.7—8.1
A 1516	11.0	+86 .3	0 .16	−0 .01	7.9—7.9
A 1627	11.0	+20 .3	0 .24	0 .00	8.6—8.6
A 1844	9.0	+78 .8	0 .26	0 .00	7.3—9.8
A 1851	10.1	+51 .6	0 .43	−0 .01	9.5—10.0
A 2100	8.8	−21 .2	0 .21	+0 .12	7.7—8.3
A 2172	8.1	−12 .8	0 .19	0 .00	8.7—9.3
A 1152	12.9	+71 .1	0 .19	0 .00	9.4—9.6
A 1609	11.0	+29 .8	0 .40	+0 .01	8.5—8.5
A 2095	8.7	−29 .5	0 .18	−0 .04	8.2—8.2
A 2167	8.1	−34 .7	0 .21	−0 .05	9.0—9.0

Measures on only one night each in 1918 were secured of the last four pairs entered in the table, but there is no question in any case of the fact of rapid motion tho additional measures may slightly alter the tabulated amount. A single measure in an intermediate year in the case of A 1152 confirms the motion; this is true also of A 2095, which forms the brighter component of Σ 2659. The fact of decided change in angle was noticed at the time of remeasuring A 1609 and A 2167 and the circle readings were therefore checked with special care.

The unusually large angular change in the pairs A 1516, A 1844 and A 1152 is noteworthy; the angular separation in the first of these is small, but since the two components are of equal brightness the pair is more readily measured than A 1844, in which the components differ greatly in brightness. Taking magnitude into account, the motion in A 1152 is more unexpected than that in either of the other pairs.

Another pair in the table which invites comment is A 1109. Nearly all the pairs tabulated here and in the three earlier lists have angular distances of one-third of a second of arc or less; the distance in this pair is not only much greater than the average but the measures indicate that it is increasing. A single measure in 1916 on a rather poor night supports this conclusion.

The remarkable change in A 519 was referred to in an earlier note[1]. Later measures confirm this and indicate a short revolution period. The record now stands as follows:

A 519

1903.04	273°.2	0″.39	3n
1916.20	180 ±	0 .10±	1n
1917.06	142 ±	——	1n
1917.81	125 .4	0 .13	1n
1918.99	76 .4	0 .14	1n

The pair is still a difficult one to measure.

Another pair listed in the same earlier note was measured again in 1918 and deserves further attention. This is A 1223, a triple system. My measures of the close pair are:

A 1223 AB

1905.53	48°.8	0″.14	3n
1915.79	9 .0	0 .16	1n
1916.54	5 .6	0 .15	1n
1918.60	344 .0	0 .15	2n

The measured distances do not accord with the indicated acceleration in angular motion; probably the first distance is a little too small, the last one somewhat too large; the fact of rapid motion, however, is beyond question. The third star, 14.5 magnitude, probably does not belong to the system, for my measures are:

A 1223 AB & C

1905.53	348°.8	1″.60	3n
1918.60	13 .0	3 .08	2n

These are consistent with a proper motion of the close pair of approximately 0″.14 annually in about 215°. The data I have been able to find in star catalogs do not suffice to establish such a motion tho the difference between the positions from Bessel's Zones and the Leipzig A. G. Catalog points to motion in the same general direction.

Robert G. Aitken.

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[1] *Publ. A. S, P.*, **28**. 277, 1916.

THE YELLOW-RED SPECTRUM OF NOVA AQUILAE NO. 3

The yellow-red region of the spectrum of novae has not been studied as extensively as the green-blue-violet region. This region has in recent years become available by the use of stained plates which make its study as feasible as that of the other part of the spectrum. Its features have been discovered and described only partially and principally in the case of *Nova Geminorium* No. 2, 1912[1], the latest nova preceding the present one, sufficiently bright to be studied.

A long series of plates of *Nova Aquilae* on fifty-one dates between June 14 and October 25, 1918, taken with one prism, has been secured at Mt. Hamilton. These plates are Seed's 27 stained with Wallace's pinacyanol-pinaverdol-homocol formula and show well the region 4800 A to 6700 A, taking in the strong hydrogen $H\beta$ and $H\alpha$. Owing to the various intensities of different features of nova spectra, these plates certainly cannot have recorded all the features that may have existed in the spectrum, but they contain a great deal of detail. A study of all the lines and bands, their positions and shifts, their structures, characteristics and developments, and their relations and associated changes, which make up a gamut of metamorphoses whose origin and meaning are yet to be learned, would require much time and printing space. The attempt here will be only to give a list of the observed bands and a few of their conspicuous characteristics. Because of many overlappings there is difficulty at places in deciding on the delimitations of the individual bands.

A descriptive list is given farther on containing a column of the spectral features measured, a column of their positions in wave-length or angstrom units, and a column of interpretations which contains brackets designating spectral bands and the wave-length of their centers followed by numbers referring to the paragraphs of description and data below. As practically all the measures, which are for the present only approximate, were made on two plates, one of June 19 and one of August 3, selected as typical of the aspect and content of the earlier and the later spectrum, the brackets have been separated into two columns in order to give some idea of the groupings of the bands at the two epochs.

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[1] Adams and Kohlschütter, *Contributions from the Mt. Wilson Solar Observatory* No. 62, III, 243, 1912; also *Ap. Jour.*, **36**, 293, 1912.

The two intense broad hydrogen bands, $H\beta$ and $H\alpha$, with their tube-comparison lines on either side, have thruout the observations stood like sign-boards along a roadway, conspicuously fixed at either end of the extent of spectrum here presented, and likewise the helium band D_3 which entered the field midway about June 20. When D_3 came in the sodium band composed of D_1 and D_2 soon vanished with its pairs of narrow absorption lines on its violetward edge and across its middle. Helium bands 4922 A and 5015 A were strong in June and gradually diminished. The nebular bands 4959 A and 5007 A, overlapping one another and the two helium bands just mentioned, developed soon after June 20 and became continually more conspicuous. The well known nebular band 5754 A has been a most conspicuous object with its central bright core intense and sharp-edged thruout the observations. Two bands, also well known, 5678 A and 6300 A, have been strong most of the time. Helium 6678 A has appeared frequently but always faintly.

Widths of bands seem to remain practically constant, their values ranging from 30 to 80 angstroms, while those of the central cores described below range from 14 to 20 A. These widths in many cases seem greater than those in other novae spectra, and this has caused some of the overlapping mentioned above.

All the brighter bands have shown central cores, some bright, that is, brighter than their respective bands, and some as absorption. The bright and absorption phases have interchanged at times in some of the bands, most conspicuously those of hydrogen, helium, and nebulium, also of 5678 A. Band cores 5678 A, He 5875 A, and 6300 A have shown changes in connection with other changes in the spectrum, as described below. The intense bright core of 5754 A has remained bright and has never been replaced by absorption during the whole interval of observation, but has shown slight variations of intensity. Its constant super-brightness and sharp definition have been remarkable.

The interpretations attempted in the subjoined columns and descriptive paragraphs are aided somewhat by the record of *Nova Geminorum*, but are nevertheless inconclusive in several cases. It may be that some of them must be taken as alternatives, unless they have different times of development or undergo complications, points which probably require more observational data and study. Altho the region 5020 A to 5068 A is definitely bright at times, its identification with helium 5047 A may be uncertain because of the overlapping bands. The relation of the bright core at 5061 A to adjacent features is quite undeterminable and the grouping 5038 A to 5084 A is only an alternative appearance. The band 5060 A to 5084 A is apparently an isolated object on some plates late in June. Band 5665 A, with limits 5634 A to 5695 A may be considered doubtful, but band 5678 A when strong, is definitely an independent band. The object 5634 A to 5708 A sometimes appears like the complex hydrogen bands when they present the double bright portions with wide absorption across the middle and less intense wings on either side. Bright band and absorption features in the regions 5786 A to 5864 A and 6419 A to 6520 A are certainly visible but very variable and any definite delimitations hardly possible. The centers 5824 A, 6457 A and 6475 A are only suggestive effects. Similar suggestions may be given for the region 5912 A to 6021 A. Object 5971 A to 6038 A is definitely the band 6004 A and the same may be quite safely decided for band 5944 A with limits 5912 A to 5976 A. But at times it is hardly possible to determine the relation of the bright core at 5960 A to adjacent features and the apparent band 5983 A between 5945 A and 6021 A may be only a transition effect.

One more group of bands difficult to dissect, lying between 6263 A and 6408 A, which have been designated definitely as two, 6304 A and 6370 A, in the case of *Nova Geminorum No. 2*, but which touch or overlap in the present nova spectrum, may still be defined as the same two with the same centers. But on only one or two plates did band 6370 A give the appearance of having a central core or of being a complete and independent band. When this group is strong it appears as one broad complex band, somewhat like the hydrogen as just referred to in connection with 5678 A, but having, instead of broad absorption across its middle, a fairly narrow sharp absorption line centered at 6331 A. The apparent middle of the portion 6263 A to 6327 A precedes the center of its frequently well-defined bright core, thus suggesting that it is cut off or overlapped by the absorption line. The definitive interpretations of the complicated regions will require thoro study.

Certain groups of bands seem to show similarities and simultaneous changes. One set, composed of bands 5168 A, 5314 A, 5577 A and 6004 A, are present in June and July with fairly sharp edges or limits. At times the individual bands are of uniform intensity and at others the first three, at least, show faintly a brightened core 17 angstroms wide. They gradually become faint and diffuse and practically vanish when a certain other set appears at its strongest. This latter set, composed of bands 5175 A, 5290 A, 5410 A and 5536 A, seems to have a recurrent nature, appearing nearly always faint, on June 26-28, July 21-23, August 3-5, August 23, and September 1. The array was conspicuous on August 3 to 5, when discovered, and gives the appearance of a group of grooves or troughs with fuzzy edges with an average of twenty-two angstroms of absorption across the middle. When these bands flash up, the cores of bands Hβ, 5678 A, and He 5875 A change from bright to absorption, the redward portions of Hβ, N_1, and He 5875 A increase in brightness, and the bright core of band 6300 A sharpens up. These concurrent changes may be associated phenomena but need further study.

The sets of bands also exhibit the relations that their widths increase with increasing wave-length and that for the second set the second differences of their positions or wave-lengths seem to approach a constant value. These relations are shown by the following table:

TABLE I

First Set				Second Set			
Wave length	1st diff.	2nd diff.	Width	Wave length	1st diff.	2nd diff.	Width
5108 A			50 A	5175 A			57 A
	140				115		
5314		117	59	5290		5	62
	263				120		
5577		164	64	5410		6	62
	427				120		
6004			67	5530			65

Whether these bands possess series relations would be of interest to discover, but this will not be undertaken here. Only the first set seems to have been observed in *Nova Geminorum No. 2*, 1912, but the second set was observed by means of orthochromatic plates in the spectrum of *Nova Persei*, 1901[3], where they appeared as very diffuse simple bright bands. The character of these bands, as shown in *Nova Aquilae No.* 3, 1918, is probably new to our knowledge of nova spectra.

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[3] Campbell and Wright, *L. O. Bull.* 1, [illegible] 1901.

TABLE II

MEASURES AND BANDS

Feature	Wave length	Interpretation			
		Bands		Centers	Note
		June 19	Aug. 3		
Beginning bright	5026A				
Beginning bright	5038			5047A	1
Bright core center	5061				2
Edge bright core	5068			5061	3
Absorption line	5070			5070	4
Ending bright	5084				
Sharp beginning bright	5140				
Beginning bright	5146			5168	5
Sharp ending bright	5196			5175	6
Ending bright	5203				
Beginning bright	5259				
Sharp beginning bright	5285			5290	6
Ending bright	5321			5314	5
Sharp ending bright	5344				
Beginning bright	5379			5410	6
Ending bright	5441				
Beginning bright	5503				
Sharp beginning bright	5545			5536	6
Ending bright	5568			5577	7
Ending bright	5609				
Beginning bright	5634				
Beginning bright	5647				
Bright, absorption, core center	5676, 7			5665 5671 5678	8 9 10
Ending bright	5695				
Ending bright	5708				

TABLE II—*Continued*

MEASURES AND BANDS

Feature	Wave length	Interpretation Bands June 19	 Aug. 3	 Centers	Note
Sharp beginning bright	5721A				
Bright core center	5754			5754A	11
Sharp ending bright	5786				
Absorption line	5824			5825	12
Beginning bright	5864				
Faint absorption line	5912			5892	13
Ending bright	5921				
Beginning bright	5945			5944	14
Beginning bright	5971			5960 5983	15 16
Ending bright	5976			6004	17
Ending bright	6021				
Ending bright	6038				
Beginning bright	6129			6158	18
Ending bright	6187				
Beginning bright	6263				
Bright core center	6300			6300	19
Ending bright	6327			6335 6331	20 21
Beginning bright	6335			6371	22
Ending bright	6408				
Beginning bright	6419				
Beginning bright	6441				
Bright core	6457			6457	23
Ending bright	6494			6475	24, 25
Ending bright	6615				
Beginning bright	6639			6676	26
Ending bright	6712				

NOTES

1. Possibly helium band with wide absorption across middle, overlapped by strong N_1 (ending at 5035A), and with wing toward the red. Appears in July and August.

2. Bright core band 14A wide.

3. Possibly band with bright core center, apparent on some plates in July.

4. Apparent band with absorption center, on some plates late in June.

5. Sharp-edged band with sharp absorption line on violetward side and bright core 17A wide, present during June and July.

6. Fuzzy-edged band with about 22 angstroms of absorption across middle, appearing at intervals during July and August, strongest on August 3-5.

7. A generally ill-defined band with bright core 17A wide, present during June, faint later.

8. Possibly a separate band with absorption core. It appears isolated on June 15, before bands 5678A and 5754A had developed, with absorption center at 5662A, but with the redward portion (center at 5677A) slightly brighter than the other.

9. Complex band most frequently ill-defined, with bright or absorption core, the portion to the violet appearing as a wing. Features sharpened on June 26-28, and at intervals afterward.

10. Band strong after June 25, sharpening at intervals with core of absorption replacing bright core. Core ill-defined, 20A wide, bright when band is not sharp.

11. Very strong well known nova band with sharp edges and stronger bright core, 15A wide, edges always sharp.

12. At times appears as a band with center at 5824A.

13. Sodium bands D_1 and D_2, strong up to June 21, then replaced by strong helium D_3 (5843A to 5907A).

14. Band with slight, unsymmetrical absorption, possibly overlapped by helium D_3, apparent in July and August.

15. Bright core, with absorption each side, appearing differently related at different times.

16. Apparent, ill-defined band following the disappearance of 6004A.

17. Faint early band with fairly defined limits and with absorption across middle at times.

18. Diffuse band, generally faint, with absorption across middle at times.

19. Strong band with middle point at 6295A, edges sharpening at intervals, particularly on August 3. Core always bright, 18A wide, not always sharp-edged, and not (on August 3) central with the apparent limits of the band.

20. These features, frequently diffuse, often appear as one broad band with narrow absorption across middle and wing sections on either side.

21. Apparently strong absorption, possibly space between two bands.

22. Probably a separate band, altho apparently without a central core, the left half being brighter than the right half.

23. Possibly center of ill-defined band (6419A to 6494A) with slightly bright core, apparent on early plates.

24. Later this portion appears as bright core with center at 6470A.

25. This interval appears as a background for Hα (6520A to 6602A), but is probably composed of a band whose center precedes Hα and of a wing to Hα on its redward side. At times absorption appears across the first part preceding the edge of Hα band.

26. Helium band with absorption across middle, always faint.

G. F. Paddock.

November, 1918.

Movements of Four Unknown Lines in the Spectrum of Nova Aquilae, 1918.

Two pairs of unidentified absorption lines which appeared intermittently in the spectrum of *Nova Aquilae* have shown conspicuous changes of position or wave-length. In each pair the two lines have appeared and disappeared together, maintained equal intensities and practically constant distances apart, moved equal amounts at the same times, and in all respects have behaved like duplicates. There seems to be, however, no definite relation of the times of appearance or disappearance of the pairs to each other; but the pair whose greatest observed wave-lengths were 4061A and 4068A always appeared and disappeared simultaneously with the sharp and narrow absorption lines of hydrogen, while the pair whose greatest observed wave-lengths were 4560A and 4576A were in general present at the times of appearance or disappearance of the other pair and the hydrogen lines, or in other words, the latter pair apparently occurred in connection with the conditions attending transition of the spectrum. When the latter pair was not seen, a band of absorption, 30 to 40 angstroms wide and of varying intensity, lay within the region 4540A to 4580A. During the absence of the former pair, a bright band 5 to 10 angstroms wide appeared in their place with center located within 1 or 2 angstroms of the recent mean position of the lines. The position of this bright band has varied less than 4 angstroms and there is no definite evidence that it is related in its origin to the pair of lines.

The first mentioned pair of lines first appeared on June 15 and their position of greatest wave-length (4061A and 4068A) occurred on June 16. From June 16 to June 25 they gradually shifted toward the violet to 4054A and 4059A and disappeared. On July 1 they reappeared with a displacement of 21 angstroms, which decreased to 4 angstroms on July 3, and then increased to 10 angstroms on July 7, when they again disappeared. They made a sudden strong reappearance on July 14 to 16, but not again thereafter. Their sudden and intense recurrence on July 2 and 14 cannot help but give the impression of a tremendously energized event at their source.

The second mentioned pair of lines have been visible during intervals of only 2 to 4 days. They first showed faintly on June 30 and on July 1 stood at their positions of smallest wave-length, 4545A and 4561A. Their succeeding wave-lengths increased to 4560A and 4576A on July 16 and then decreased to 4549A and 4564A, which are approximately the same as those of their earliest appearance. They thus seem to have shifted toward the red, in opposite direction to the movement of the other pair, but the direction of shift cannot be stated without establishing their normal places or wave-lengths, which is impossible here.

Corresponding to the great displacement of the first pair on July 1, it is found that the second pair present their farthest position toward the violet on the same date. Aside from these extreme positions, which occurred abruptly, briefly, and but once, the displacements have amounted to 10 and 12 angstroms respectively for the two pairs of lines. The distance between the two lines of the first pair has ranged from 5 to 7 angstroms and that of the second pair 14 to 17 angstroms. These variations are probably due to changing widths and appearances, and it is very probable that the lines possess a constant difference of wave-length.

Date, 1918	Displacements From 4061A	Displacements From 4068A	Description	Displacements From 4500A	Displacements From 4570A	Description
June 15	− 2A	− 4A	Diffuse	A	A	
16	0	0	"			
18	− 2	− 3	"			
19	− 2	− 2	"			
20	− 2	− 3	Fair			
21	− 3	− 4	"			
22	− 4	− 4	"			
23	− 6	− 7	Diffuse			
24	− 4	− 4	Fair			
25	− 7	− 9	Good			
26	− 6		Center of bright band			
27	− 6					
28	− 6					
29	− 6					
30				−12	−12	Faint
July 1	−21	−21	Fair	−15	−15	Diffuse
2	− 8	− 8	Strong, wide			
3	− 4	− 5	" "			Absorption band
4	− 5	− 6	" "			
5	− 6	− 7	Fairly sharp			
6	− 7	− 8	Sharp			
7	− 9	−10	"	− 4	− 2	Fair
9	− 4		Center of bright band	− 0	− 0	Fair
10	− 4					Absorption band
12	− 3					
14	− 9	−10	Sharp	− 3	− 2	Sharp
16	− 8	− 8	Sharp, strong	0	0	Sharp, strong
18	− 5		Center of bright band	− 0	− 0	Fair, strong
19	− 4					Absorption band
21	− 4					
23	− 5					
25	− 4			− 8	− 7	Fair
28	− 6			−11	−13	Faint
Aug. 5	− 4					Absorption band
8	− 7			−11	−12	Faint
11	− 4					

The accompanying table contains approximate measures of the displacements of the lines toward the violet from their positions of greatest observed wave-lengths, together with their dates and brief descriptions, from which the progressive and sudden shiftings of the lines and the relative times of their occurrence can easily be seen.

G. F. PADDOCK.

January, 1919.

HISTORICAL LETTER RELATING TO THE 36-INCH TELESCOPE

Mr. Ambrose Swasey has courteously given us permission to publish the following letter which we believe will be of interest to all members of our Society.—PUBL. COM.

July 31, 1896.

MR. J. F. HOLLOWAY,
Buffalo, New York.

DEAR FRIEND HOLLOWAY: Thinking it may be of interest to my friends I will relate some of the incidents that occurred during the time I was engaged in the erection of the Lick Telescope.

In the fall of 1887, the instrument was shipped to San Jose, California, and conveyed by team to the observatory on Mount Hamilton, which is about 4500 feet high[1] and thirteen miles distant in direct line and twenty-seven miles by road. The people of San Jose took great interest in everything that pertained to the Lick Observatory, and were especially interested in the powerful instrument that was to be placed in the great dome, which could be clearly seen from any part of the city. Every one having anything to do with the observatory or its instruments received special attention, and I was often smilingly met by "Good-morning, Professor Swasey"—thinking of course that was the proper title to give one engaged in the construction of astronomical instruments.

The great sections of the telescope, weighing several tons, were loaded on trucks drawn by six or eight unfortunate beasts, sometimes called horses. There were usually two drivers—the duty of one being to hold the lines and ride, while the other walked along by the side of the animals, and pelted them with stones, when extra energy was needed to revive their spirits in climbing the many long and steep grades. When they arrived at the top of the mountain, one could easily imagine the poor creatures—nearly dead from exhaustion—saying to one another: "This may be all right for science, but it is mighty hard on horseflesh."

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[1] Later, the elevation of the marble floor of the observatory above mean-tide level was determined to be 4,209 feet.—PUBL. COM.

We had a great many kinds of weather on the mountain; the wind often blew from sixty to seventy-five miles per hour, and on one occasion it reached eighty, and no one knew how much higher for at that speed the anemometer blew off and landed in the valley a long distance away. It was not possible to walk from one building to another without holding on to something for fear of being blown off the mountain into the canyon nearly a thousand feet below. On another occasion we had such a severe snow storm that all communication was cut off from San Jose for several days, and as it was impossible to get at the fire wood on the side of the mountain on account of the snow, we were obliged to burn the boxes in which the great telescope was packed in order to keep warm.

After the telescope was in working order and the object glass placed in position, on the evening of January 3, 1888, Capt. Floyd, president of the Lick trustees, Professor Keeler, the astronomer in charge, Mr. Alvan Clark and myself went to the observatory to observe the stars for the first time through the great instrument. Mr. Clark pointed the instrument on one of the prominent stars, and commenced to adjust the focus. After working for some time, moving the eye-piece out and in to the fullest extent of its adjustment, he could not bring the star into focus. We all stood there in perfect silence waiting for the first observation, but seeing that Mr. Clark could not possibly adjust the focus, I broke the spell by saying: "Well, it is quite evident that the tube is too long or the focus is too short." It was then nearly midnight, and we left the instrument and went to our rooms. Quite early in the morning, however, I went to the observatory and there found Mr. Clark as anxious as I to find out the cause of the difficulty. After measuring the focal length of the instrument, which was quite a difficult task with the means at our disposal, we found that it was 56 feet instead of 56 feet 6 inches, the length given us. Mr. Clark at once said, "We have made a mistake and have given you the focus six inches too long." I then directed our men to cut off six inches from the objective end of the great tube, and on the evening of January 7, the cell and all the accessories were back in their positions and the first successful observations were made. I remember they accorded me the honor of being the first to observe the Planet Saturn through the great instrument, and I still have the beautiful drawing of the planet, as it appeared that evening, which Professor Keeler made for me.

Professor Holden, who had been appointed director of the observatory, was then president of the University of California. On my invitation he visited the observatory in order to inspect the instrument before I left for the East, and I shall never forget the look of wonder and surprise as he entered the dome and saw before him for the first time the great instrument. The mechanism of the finder not having been adjusted, I stepped upon the tube of the telescope to remove the finder cap. Professor Holden sang out to me—"Is that what you do, walk on a telescope that way?" "Yes," I said, "I have seen a dozen men on this tube at one time." He did not realize that the great instrument before him, of which he was about to take charge, had not only an objective which was the most powerful light gatherer ever made, but that from an engineering standpoint it was the most powerful instrument ever constructed.

Very respectfully,

(signed) AMBROSE SWASEY.

THE FOCAL LENGTH OF THE 36-INCH REFRACTOR

In Dr. Swasey's interesting note, which precedes, the focal length of the 36-inch Lick refractor is given as approximately 56 feet. Evidently this value, which is stated in the first published description of the instrument[1] as 674 inches (56 feet 2 inches), refers to the length of the large tube of the telescope, since the focal length of the 36-inch lens for the visual rays, determined in the usual way from micrometric measures, is 694 inches[2] (57 feet 10 inches). It seems worth while to call attention to these facts as the erroneous value has been quoted in various places, especially in Young's *General Astronomy*.

J. H. MOORE.

NOTE ON COMET *d* 1918 (SCHORR)

The fourth comet of 1918 was discovered by R. Schorr, director of the observatory at Bergedorf, near Hamburg. It was found on November 23rd, but the cabled announcement, thru Copenhagen, did not reach American astronomers till the 29th.

On the evening of the 29th, an observation was secured by Burton at the Naval Observatory, Washington. On the next night it was observed by Burton again, and also by Barnard at the Yerkes Observatory and by Aitken at the Lick Observatory. Several more observations were secured during the early part of December.

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[1] *Publ. Lick Obs.*, **1**, 61, 1887.

[2] *Ibid.*, **3**, 1, 1894.

As usual, the elements of the orbit of the comet were determined at the Berkeley Astronomical Department. The first orbit was based on the first three observations received. The second orbit, based upon a longer arc, and with observations better distributed, was published in *Lick Observatory Bulletin* Number 320. The two sets of elements are quite similar—they agree in making the orbit elliptical, with a period of about six years. So far this comet has not been identified with any of the previously known comets; it appears to be a new member of the already numerous family of comets belonging to *Jupiter*.

According to the last elements, the comet passed perihelion on October 16th. The distance from the Sun at that time was about 180,000,000 miles. At discovery it was about 95,000,000 miles from the Earth. The distance from both the Earth and the Sun is now increasing, and the theoretical brightness, for that reason, is diminishing. The elements, beyond the elliptic character, with an unusually small eccentricity, have no points of special interest.

An estimate of the brightness was made by Barnard in the early part of December. The magnitude, on the stellar scale, was sixteen, or perhaps a trifle brighter. The comet is therefore visible only in large telescopes. Before many weeks it will be entirely beyond the range of visual observation.

H. M. JEFFERS.

Berkeley Astronomical Department,
January 15, 1919.

GENERAL NOTES

An Introductory Treatise on Dynamical Astronomy[1].—No attempt will be made in this note to present a "review" of Professor Plummer's book; for, in the first place, an adequate review could be written only by a specialist in dynamical astronomy, and, in the second place, such a review would of necessity be too technical in its phrasing to be suited to the pages of these PUBLICATIONS. The note is intended simply to call attention to an excellent book which fills a gap in English astronomical literature. The only other book known to me, which is written in English and which is readily accessible to students, that aims to present a general introduction of the theory of motion under the law of gravitation is Professor Moulton's *An Introduction to Celestial Mechanics*, and in content as well as in form of presentation the two books differ widely.

The first six of the twenty-four chapters of Professor Plummer's book deal with "preliminary matters," the fundamental propositions and relations that lead to the discussion of methods of orbit determination, to which the next five chapters are devoted. In his Preface the author says that the latter section "is in no sense complete and is not intended to replace those works which are entirely devoted to this subject. Otherwise it would have been necessary to describe in detail such admirably effective methods as Professor Leuschner's..." Notwithstanding this explanation, regret must be expressed that these methods have been omitted, for by actual use in the computation of orbits of comets, asteroids and satellites they have proved their great value and wide applicability. On the other hand, it is a pleasure to note that two of the five chapters in this section present an excellent discussion of the theory of orbits of visual and spectroscopic binary star systems.

Seven chapters are devoted to the problems of perturbations, the first one dealing "exclusively with abstract dynamical principles which are subsequently employed." One chapter is given to the restricted problem of three bodies, and two to lunar theory. The three closing chapters treat respectively of precession, nutation and time; libration of the Moon; and formulae of numerical application.

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[1] *An Introductory Treatise on Dynamical Astronomy*, by H. C. Plummer, M. A., Andrews Professor of Astronomy in the University of Dublin and Royal Astronomer of Ireland. Cambridge University Press, 1918. Large 8vo., cl. Price, 18 shillings net.

A somewhat careful reading of the section devoted to orbit determinations shows that the book will appeal primarily to the student of astronomical theory rather than to the practical computer: but Professor Plummer is himself a skillful computer and has succeeded in his effort "to leave no formulae in a shape unsuitable for translation into numbers."

R. G. AITKEN.

Dr. Michel Luizet.—The untimely death on November 20, 1918, of Dr. M. Luizet, assistant astronomer at the Observatory of Lyons, has removed from the field of variable star astronomy one of its most active and successful workers. For many years he has been the leading observer of variable stars in France, and indeed few students in this branch of astronomy anywhere in the world have equalled him in the quantity, quality and continuity of his work. His contributions are to be ranked with those of the leaders in the science, such as Argelander, Schmidt, and E. C. Pickering.

Luizet's work has been accomplished with small telescopes and without the aid of special photometric equipment. Instead of modern photometers and extensive research facilities, his assets have been methodical perseverance and a good appreciation of the problems immediately before him. His variable star observations, begun more than twenty years ago, have been carried on in addition to exacting routine meteorological duties.

Perhaps his singleness of purpose is the chief reason that Luizet's name will endure in the history of variable star observation. My bibliography of his papers contains 115 titles, and all but four of them concern variable stars. He dealt with observation rather than interpretation. Cepheid variables and eclipsing binaries received particular attention from him; and his work on certain stars of the eclipsing type have been of especial value in studies of stellar density. Our knowledge of variable stars has not gone so far that progress can be made only by very exact instruments. Careful visual estimates can still contribute valuable results, not only in determining periods of light variation, but also occasionally, as with Luizet's work, in giving light-curves suitable for orbital analysis—suitable, therefore, for the derivation of the dimensions, luminosities, and densities of the stars themselves.

That the maximum light of an eclipsing star is as important as the minimum, was fully appreciated by Luizet, and more than once by paying careful attention to all phases of the light variation, he has discovered shallow secondary minima or curved maxima. Fortunately he has had the foresight and endurance to work on difficult eclipsing stars of long period. These objects belong to the redder spectral types and are of low density; knowledge of them contributes, therefore, directly to the problem of the order of the evolution of stars.

We note in concluding that Luizet's work has been mainly of the kind that sustains the proudest tradition of astronomy, that is, the intelligent accumulation of observations, unhampered by preconceptions and unprejudiced by hypotheses. He leaves to others the deduction from his observations of facts relating to the nature of stellar evolution; he little suspected, probably, that his monograph proving the unchanging period of *Delta Cephei* would be of value later in the problem of the age of stars. His task primarily has been to add piece by piece to the sum of knowledge in his chosen branch of science, and that task he has accomplished well.

HARLOW SHAPLEY.

A Note on the Size of the "Hydrogen Envelop Star"—Campbell's[1] hydrogen envelop star, B. D. +30° 3639, according to Wright[2] is a Wolf-Rayet star with a gaseous nebula for an envelop or a planetary nebula with a stellar nucleus. The approximate size of this interesting object may be found from available data.

The apparent diameter of the hydrogen envelop has been determined with the aid of a spectroscope by Campbell visually and by Wright photographically. The values obtained, 5″ and 7″ respectively, agree excellently, considering the difference in the methods employed tending to make the former too small and the latter too large, as pointed out by Wright. For this reason the mean value, 6″, represents the apparent diameter of the hydrogen disk with a higher degree of precision than is mathematically evident.

The parallax of the star was determined theoretically by Gyllenberg.[3] On account of the difficulties involved it is quite remarkable that the distance of such an object should be known even approximately. Several assumptions in the method employed, e. g., that the stars of Class O have equal individual temperatures as well as masses, may be open to question; but the value obtained for the parallax, 0".006, will be accepted for the purpose of this note.

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[1] *Astron. and Astroph.*, **13**, 462, 1894.

[2] *Ap. Jour.*, **40**, 469, 1914.

[3] "The Distribution in Space of Stars of the Spectral Type O," p. 13, 1917. *Arkiv. for Matematik, Astronomi och Fysik*, Band 11, No. 28.

The size of the hydrogen envelop follows directly from the apparent diameter and the parallax, giving 6÷0.006 or 10,000 astronomical units for the true diameter. The radius of the envelop is accordingly about 170 times the distance of *Neptune* from the Sun or 1/55 the distance of the nearest star.

The absolute magnitude of a Class O star according to Gyllenberg is −2.78 at a distance of one Siriometer or 1,000,000 astronomical units. At the distance of the Sun the magnitude would be −32.9. Using −26.5 (Abbot) as the magnitude of the Sun, we find that the star is about 400 times brighter than our luminary.

W. CARL RUFUS.

Detroit Observatory,
University of Michigan.

On the Rotation of Celestial Bodies.—Messrs. Shinzo Shinjo and Yoshikatsu Watanabe have an interesting paper on this subject in the *Memoirs of the College of Sciences, Kyoto Imperial University* (Vol. III, No. 7, 1918). The paper consists of two parts, (1) a numerical determination of the masses and angular momenta of those binary star systems for which the parallaxes have been measured and for which orbits have been computed or for which "probable values" of the elements needed can be derived with more or less certainty from the observed motions; (2) a theoretical determination of the angular momentum of a swarm of meteorites isolated from external influences and initially in spherical symmetry. In the comparison of the results of the two computations the authors find the basis for their theory that the stellar systems have evolved from primordial swarms of meteorites isolated from one another, the constituent bodies of a swarm being comparable in size with our present asteroids. In the variation in the size of the meteorites (and presumably of the swarm) they find the conditions determining the evolution into single, double or multiple systems. The gaseous nebulae are explicitly excluded.

The data of observation on which these conclusions rest are necessarily of very unequal value. Some of the parallaxes may be regarded as very accurate, others as quite uncertain. This remark applies also to the orbit data, even for those systems for which orbits are available, and still more to those for which "probable values" of the necessary elements are taken from the observed motion over small arcs. The uncertainties in the parallaxes, as the authors themselves point out, are the more important. Hence, altho they conclude that, "broadly speaking," the masses and angular momenta of the 86 systems are "of about the same order of magnitude," it is not surprising that individual values range from 0.15 ⊙ to 7.45 ⊙ for the masses, and from 0.30 ⊙ to 161 ⊙ for the angular momenta.

Professor Hale and the Royal Astronomical Society. The following paragraph is copied from the department "From an Oxford Note-Book" in *The Observatory* for December, 1918.

> The "second Friday" in November could not, of course, hold a candle (even a war candle) to the second Monday—"The Day" for which Germany has been longing so long—but it was nevertheless notable. The Royal Astronomical Society reassembled under conditions very different from those under which they had last met in June; and they had the pleasure of welcoming Hale, who told them about the 100-inch amid great enthusiasm. The meetings of the Society are followed by a club-dinner of a domestic character; but it would be straining reticence beyond reasonable limits not to mention that at that particular dinner Hale was elected by acclamation an Honorary Member of the Club "any rule or custom to the contrary notwithstanding," the unprecedented election being symbolical of that new union of the United States with England which had found so splendid an expression in war, and which, it is confidently hoped, will develop into a more enduring co-operation in peace. Hale made a great speech on the occasion, but here it will be proper to relapse into privacy—not for fear of the censor, but because some things strike too deep for written words.

Charles William Adams.—We have received from Dr. Charles E. Adams, Government Astronomer of New Zealand, a brief biographical sketch of his father, the late Charles William Adams, who was one of the pioneers in astronomical and geodetic work in New Zealand. Mr. Adams spent forty-two years of his long life in the Survey Department, holding many important positions, and his published papers relate chiefly to subjects in geodesy and general surveying. In later years he was also connected with the Hector Observatory, rendering valuable service as observer for time and as adviser on methods of professional procedure.

The most unusual incident in his astronomical career, however, was his successful challenging of the accuracy of the declination of

α^2 *Centauri*, as recorded in the English *Nautical Almanac* in the 1870's, on the basis of his latitude observations at three stations *with an 8-inch theodolite;* for as his biographer says, "generally speaking, surveyors and sea captains swear by the *Nautical Almanac*. In their opinion the Bible *may* be true, but the *Nautical Almanac must* be true. Sir George Airy, Astronomer Royal at the time, candidly acknowledged the correctness of Mr. Adams's observations.

The Practical Observing of Variable Stars.—We have received from Mr. Charles E. Barns, of Morgan Hill, California, an attractive little pamphlet with the above title which may be recommended without reserve to all members of our society who are interested in the variable stars. The contents, contributed by members of the American Association of variable Star Observers, consist of short papers, original or compiled from standard authorities, every one of which is of practical value to the amateur observer. A list of variables taken from *H. C. O. Circular 166*, and a list of atlases and books of reference add to the usefulness of the booklet. Mr. Barns generously offers to forward copies to any members of the Astronomical Society of the Pacific who wish to engage in the study of variable stars.

Recent Medal and Prize Awards.—The Royal Society of London has awarded a Royal Medal to Professor Alfred Fowler for his researches in spectroscopy, and, in particular, for his extraordinary success in the identification and reproduction of celestial spectra in the laboratory.

The French Academy of Sciences has awarded the Prix Lalande to M. A. Belopolosky of the Poulkovo Observatory, Russia, for his work in astronomical spectroscopy; the Prix Valz to M. Frédéric Sy of the Algiers Observatory for meridian circle and photographic observations during the past thirty years; and the Prix Janssen to Father Stanislas Chevalier of the Zô-Sè Observatory, Shong-Haï, for services to astronomy and especially for his solar studies.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, ON SATURDAY, JANUARY 25, 1919, AT 7.30 P. M., IN THE OFFICE OF MR. FRANK V. CORNISH, UNDERWOOD BUILDING, SAN FRANCISCO, CALIF.

In the absence of President CAMPBELL, the Chair was occupied by First Vice-President BEVERLY L. HODGHEAD.

Mr. A. L. BLACK was elected a life member of the Society.

Mr. C. H. ADAMS was elected as an active member.

The Phoenix, Arizona, Public Library was elected as an institutional member.

On motion of Director CUSHING, it was declared to be the sense of the Board that an award of the Bruce Gold Medal should be made for the current year.

The Secretary read communications from the Secretary of the Pacific Division of the American Association for the Advancement of Science, and from Doctors Campbell and Aitken, relative to the participation of the Astronomical Society of the Pacific in the forthcoming meeting of the Pacific Division. A vote was taken, showing it to be the sense of the Board that this Society should be properly represented on the said occasion. The following committee of arrangements, with full power to act, was appointed by the Chair:

Dr. HARLOW SHAPLEY, of Mt. Wilson Solar Observatory, Chairman.
Dr. GEORGE E. HALE, of Mt. Wilson Solar Observatory.
Dr. W. W. CAMPBELL, of Lick Observatory.
Dr. R. G. AITKEN, of Lick Observatory.
Dr. S. D. TOWNLEY, of Stanford University
Dr. V. M. SLIPHER, of Lowell Observatory.
Dr. S. L. BOOTHROYD, of Washington University.
Dr. A. O. LEUSCHNER, of University of California.

The Chairman of this committee was authorized, in his discretion, to add other members to the committee.

Adjourned.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD ON SATURDAY, JANUARY 25, 1919, AT 8.00 P. M., IN THE OFFICE OF MR. FRANK V. CORNISH, UNDERWOOD BUILDING, SAN FRANCISCO, CALIF.

The Chair was occupied by First Vice-President **BEVERLY L. HODGHEAD.**

The minutes of the last annual meeting, as printed in the PUBLICATIONS of February, 1918, were approved without reading.

Director CUSHING, Chairman of the Finance and Auditing Committee, reported that an examination of the Treasurer's accounts showed them to be correct and in good order. A verbal synopsis of the Society's financial condition was made by Mr. CUSHING, after which the following report of the Treasurer was submitted and ordered placed on file.

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING JANUARY 25, 1919

GENERAL STATEMENT

Assets.	
Twenty-five bonds (face value $19,900.00)—Cost	$20,054.69
Cash as follows:	
Alvord Fund	210.51
Library Fund	195.96
Bruce Medal Fund	436.42
Life Membership Fund	222.41
Dolbeer Fund	301.51
Donohoe Comet Medal Fund	73.16
Stahl Lecture Fund	155.32
General Fund	693.33
Total	$22,343.31
Liabilities, none.	

STATEMENTS BY FUND

The Alvord Fund

Dr. To cash balance January 26, 1918			$ 400.39
Interests received			238.10
Total			$ 638.49
Cr. By transfers to General Fund		$ 227.98	
Purchase 3d Liberty Bonds		200.00	427.98
Balance, January 25, 1919			$ 210.51
Holds 6½ Bonds, par value	$4,700.00		
Cost value	4,570.25		

The Library Fund

Dr. To cash balance January 26, 1918			$ 188.36
Interests received			197.60
Total			$ 385.96
Cr. By transfers to General Fund			190.00
Balance January 25, 1919			$ 195.96
Holds 3½ Bonds, par value	$3,500 00		
Cost value	3,573.75		

Bruce Medal Fund

Dr. To cash balance January 26, 1918		$ 277.31
Interest received		159.11
Total		$ 436.42
Balance January 25, 1919		436.42
Holds 3½ Bonds, par value	$3,000.00	
Cost value	2,987.22	

Life Membership Fund

Dr.	To cash balance January 26, 1918		$ 395.53
	Interests received		127.14
	From life memberships		350.00
	Total		$ 872.67
Cr.	By transfers to General Fund	$ 100.26	
	Purchase Liberty Bonds	500.00	
	Membership dues refunded	50.00	$ 650.26
	Balance January 25, 1919		$ 222.41
Holds 4	Bonds, par value	$3,000.00	
	Cost value	2,996.25	

Comet Medal Fund

Dr.	To cash balance January 26, 1918		$ 36.36
	Interests received		36.80
	Total		$ 73.16
	Balance January 25, 1919		73.16
Holds 1	Liberty Bond, par value	$1,000.00	
	Cost value	1,000.00	

Dolbeer Fund

Dr.	To cash balance January 26, 1918		$ 486.88
	Interests received		232.61
	Total		$ 719.49
Cr.	By transfers to General Fund	$ 217.98	
	Purchase Liberty Bonds	200.00	417.98
	Balance January 25, 1919		$ 301.51
Holds 6½	Bonds, par value	$4,700.00	
	Cost value	4,727.22	

Stahl Lecture Fund

Dr.	To cash September 29, 1917		$1,000.00
	Interests received		19.53
	Total		$1,019.53
Cr.	By expenditures to date		864.21
	Balance January 25, 1919		$ 155.32

The General Fund

Dr.	To balance January 26, 1918		$ 745.41
	Dues		1,059.00
	Dolbeer Fund		417.98
	Bruce Medal Fund		145.62
	Montgomery Library Fund		190.00
	Alvord Fund		427.98
	Life Membership Fund		560.62
	Stahl Lecture Fund		422.15
	Stahl Book Fund		87.56
	Donohoe Comet Medal Fund		35.00
	Sale of Publications		74.73
	Refunded for Reprints		92.53
			$4,258.58
Cr.	By Sunset Publishing House	$1,342.22	
	Knight-Counihan	70.00	
	Stahl Lecture Fund	431.15	
	Stahl Book Fund	87.56	
	Alvord and Dolbeer Funds	420.00	
	Bruce Medal Fund	145.62	
	Life Membership Fund	360.00	
	Comet Medal Fund	35.00	
	Typewriter	77.50	
	Lecture July 15, 1918	25.00	
	Salary Secretary	300.00	
	Office rent	120.00	
	Barnard refund	50.00	
	Binding	24.95	
	Postages	34.25	
	Taxes	16.87	
	Safe Deposit Box	5.00	
	Engraving	3.18	
	Insurance	4.95	
	Check returned	5.00	
	Expressage	1.15	
	Incidentals	5.85	3,565.25
	Balance January 25, 1919		$ 693.33

SECURITIES HELD BY THE SOCIETY

			Par Value
2	South Pacific Coast R. R. Co	at 4 %	$2,000.00
3	Los Angeles Gas and Electric	at 5 %	3,000.00
2	Oakland Transit	at 5 %	2,000.00
3	East Bay Water Co	at 5½%	3,000.00
2	Blue Lakes Water Co	at 6 %	2,000.00
2	Edison Electric Co	at 5 %	2,000.00
2	Bay Counties Power Co	at 5 %	2,000.00
1	Moulton Irrigated Lands Co	at 6 %	1,000.00
1	First Liberty Loan	at 3½%	1,000.00
2	Second Liberty Loan	at 4 %	1,000.00
4	Third Liberty Loan	at 4¼%	400.00
1	Fourth Liberty Loan	at 4¼%	500.00
25	Bonds		$19,900.00
	Par value	$19,900.00	
	Cost value	20,054.69	

The report of the Treasurer for the fiscal year ending January 25, 1919, has been examined and found correct.

Charles S. Cushing,
A. H. Markwart,
B. A. Baird,
Auditing Committee.

During the year 1918 the following new members have been received:

Life Members	5
Active Members	37
Total	42
Resignations	10
Deaths	5
Dropped for non-payment of dues	10
Total separations	25

REPORT OF THE COMET MEDAL COMMITTEE

Mount Hamilton, January 15, 1919.

Four comets have been reported for the year 1918; two of these were unexpected, and two were well known periodic comets.

1918*a*—Unexpected comet discovered by Reid, at Cape Town, South Africa, on June 12, 1918. Beyond the discovery announcement nothing further has been published in the astronomical journals to date, and it would therefore appear that the discovery has not been confirmed.

1918*b*—The return of Wolf's periodic comet was observed at Greenwich on July 9, 1918, by Jonckheere, and independently by Barnard at the Yerkes Observatory on July 12, 1918.

1918*c*—The return of Borrelly's periodic comet was observed by Fayet at the Nice Observatory on August 7, 1918.

1918*d*—An unexpected comet was discovered by Schorr at the Hamburg Observatory on November 23, 1918.

Formal action as to the award of a Donohoe comet medal for the discovery of comet *a* has not been taken, pending the receipt of further and more detailed information from Mr. Reid.

Action concerning the award of the Donohoe comet medal for the discovery of comet 1918*d* has not been taken, on account of prevailing international conditions.

In last year's report was recorded the return of Encke's periodic comet, as observed by Schorr at Hamburg on December 30, 1917. This comet was also observed independently by Reid at Cape Town on December 31, 1917.

Respectfully submitted,

Committee on the Comet Medal:
W. W. Campbell,
J. H. Moore,
Sturla Einarsson.

The report of the Library Committee, Mr. Cornish, Chairman, showed the total number of books and documents on hand to be 5,902, of which 621 are bound volumes. A total of 860 pamphlets and 10 bound volumes were added during the year.

Election of officers for the ensuing year being the next business in order, the following report was made by the Committee on Nominations, which consisted of Messrs. Frank V. Cornish, Prof. George C. Edwards and Dr. Sturla Einarsson:

For Board of Directors

R. G. Aitken
J. C. Cebrian
G. E. Hale
W. H. Crocker
C. S. Cushing

Beverly L. Hodghead
A. H. Markwart
Bernard Benfield
J. Costa
Mrs. Isaac Roberts

D. S. Richardson

For Publication Committee
R. G. Aitken, J. H. Moore and H. Shapley

No other nominations being made, the Secretary was instructed by the meeting to cast the ballot for the persons named, which he did, and they were declared by the Chair to be the duly elected officers of the Society for the ensuing year.

Adjourned.

Minutes of the Newly Elected Board of Directors of the Astronomical Society of the Pacific, held on Saturday, January 25, 1919, at 9.00 p. m., in the Office of Mr. Frank V. Cornish, Underwood Building, San Francisco, Calif.

The Board proceeded to organize by electing the following officers to serve during the ensuing year:

President	Beverly L. Hodghead
First Vice-President	R. G. Aitken
Second Vice-President	Mrs. Isaac Roberts
Third Vice-President	J. Costa
Secretary-Treasurer	D. S. Richardson

The following standing committees were appointed by President Hodghead:

Finance—C. S. Cushing, W. H. Crocker, A. H. Markwart.

Comet Medal—W. W. Campbell, J. H. Moore and Sturla Einarsson.

Library—Frank V. Cornish, Mrs. Isaac Roberts, D. S. Richardson.

Adjourned.

D. S. Richardson, *Secretary.*

OFFICERS OF THE SOCIETY.

BEVERLY L. HODGHEAD	*President*
R. G. AITKEN	*First Vice-President*
MRS. ISAAC ROBERTS	*Second Vice-President*
J. COSTA	*Third Vice-President*
D. S. RICHARDSON	*Secretary and Treasurer*

Board of Directors—WM. H. CROCKER, C. S. CUSHING, B. L. HODGHEAD, A. H. MARKWART, D. S. RICHARDSON, J. COSTA, MRS. ISAAC ROBERTS, R. G. AITKEN, J. C. CEBRIAN, GEO. E. HALE.

Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
Finance Committee—C. S. CUSHING, W. H. CROCKER, A. H. MARKWART.
Library Committee—D. S. RICHARDSON, F. V. CORNISH, MRS. ISAAC ROBERTS.
Donohoe Comet-Medal Committee—W. W. CAMPBELL, JOSEPH H. MOORE, STURLA EINARSSON.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 128 Lick Building, 35 Montgomery Street, San Francisco, California. Subscription price, $5.00 per year.

Edward Charles Pickering

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXXI. San Francisco, California, April, 1919 No. 180

EDWARD CHARLES PICKERING, 1846-1919

It is the way of the world; perhaps not an unwise provision of Nature, in the long run of the human family, but certainly in general the source of our deepest regrets and sorrows.

The passing of Professor Pickering on February 3rd, in the seventy-third year of his life, has brought grief to an uncommonly wide circle of friends, for his merits included rare personal charm as well as great scientific ability and activity. That he was the most unselfish of men was discovered by all who discussed with him, in person or thru correspondence, the problems of their professions. Harvard College Observatory, under Pickering's directorship of fully forty-two years, was famous for its large-scale development and pursuit of astronomical research in new fields, and almost equally famous for the spirit of helpfulness to other observatories and to astronomers in many lands.

Professor Pickering's life was singularly active and efficient. He obtained an early start in his career, and he died in the harness. At twenty-one years of age he became professor of physics in the Massachusetts Institute of Technology, and but a day or two before his death he called several assistants to his bedside to discuss with him many ideas concerning Harvard Observatory work ahead. While in the Institute he established the first physical laboratory in America, and wrote an excellent and extensive textbook on the Elements of Physical Manipulation, as a laboratory guide. On February 1, 1877, in his thirty-first year, he became director of Harvard College Observatory. His administration was remarkable from beginning to end for originality and energy. His training in physics inclined him to apply the principles and instruments of the physical laboratory as auxiliaries to the telescope in the study of the stars. He made provision for continuing and extending the work of the Harvard meridian circle in determining the accurate positions of the stars in accordance with the plans of the Astronomische Gesellschaft, but the immediate responsibility for the meridian work was with Professor Rogers and Professor Searle, successively. Pickering's own labors and the further expansion of the Observatory's work during the forty-two years related almost exclusively to researches on the brightness of the stars and the spectra of the stars. This radical departure from conventional observatory policy caused him to be criticised severely by many astronomers older than himself, but not many of his critics were his juniors in years, as the rapid passing of time fully justified his methods and purposes. His vision as to the immense richness of fields of investigation first entered, on small scales, by Secchi, Rutherfurd, Huggins, Vogel, and Henry Draper, his courage and his scientific and executive abilities, have given wonderful assistance in developing that side of astronomy known as Astrophysics.

Professor Pickering was one of the first to realize, in 1883, some of the possibilities of photography in astronomical research, and from that date the new instruments and the new methods of Harvard College Observatory have been mainly photographic. He was the first to show that photographs obtained with small telescopes and suitable equipment of prisms will record delicate features of stellar spectra far beyond what the eye can detect, even with the assistance of the most powerful telescopes in existence. The application of the photographic method to the study of stellar spectra at Harvard College Observatory was stimulated and efficiently supported on the financial basis of the Henry Draper Memorial, established in 1885 by Mrs. Draper in honor of her distinguished husband, who had been the first to succeed in photographing a stellar spectrum which showed the spectrum lines.

Professor Pickering realized the need for extending his programs of observation to stars distributed over the entire sky. Fortunately, and by virtue of Director Pickering's success, there came to Harvard College Observatory the Boyden Fund of $230,000 for astronomical investigations to be made at high altitudes above sea level. This fund was used to establish and maintain the Arequipa Observatory in Peru.

The systematic photography of stellar spectra at Cambridge and Arequipa has led to results of priceless value, of which we mention only two:[1]

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[1] A more detailed account of Professor Pickering's activities and successes than is here attempted has already been published by the Astronomical Society of the Pacific on the occasion of awarding the Bruce Gold Medal to Professor Pickering in the year 1908. See *Pub. A. S. P.*, **20** 55 1908.

1. The Harvard catalogs of stellar spectra, thus far published, contain descriptions of the spectra of more than 26,000 of the brighter stars. *The* (new) *Henry Draper Catalogue* of stellar spectra, now in manuscript, and going thru the press, will describe the spectra of about 222,000 stars distributed over the entire sky. The finished catalog will consist of nine thick quarto volumes. Unfortunately Professor Pickering lived to see only two of the nine volumes thru the press. It is impossible to overestimate the value of this catalog and its Harvard predecessors to all students of the stars, whether they are interested in determining what the stars are, what their history has been and will be, where the stars are, or whither they are going. It should be said that we are indebted to Miss Annie J. Cannon, of Harvard Observatory, for the faithful, able and extensive work of examining critically the photographs upon which this catalog is based, and for the resulting descriptions of the individual spectra. It is interesting to note that Professor Pickering made the very expensive publication of *The Henry Draper Catalogue* a charge against his personal fortune. It is believed that he frequently gave of his own resources to further the astronomical plans, not only of Harvard Observatory, but of other institutions and of individuals.

2. A profound study of the spectra of the naked eye stars by Professor Pickering and some of his chief assistants, notably Miss Maury, Mrs. Fleming, and Miss Cannon, led to the formulation of the Harvard system of stellar classification. The high esteem in which this system is held may be inferred from the fact that the international committee of astronomers within the Solar Union unanimously recommended its adoption in current astronomical research.

The brightness of nearly 50,000 stars has been measured at Cambridge and Arequipa, in major part by Professor Pickering personally with photometers of his devising. His own measures of the brightness of the northern stars number more than one and a half millions. The results of all these observations form an invaluable system of stellar magnitudes that is in almost universal use.

The Harvard discoveries of variable stars number 3,435 to date. This is more than two-thirds of all the known variables. These were discovered in nearly all cases by photographic methods.

A unique program of observation at the Harvard Observatory consists in the rapid photography of the night sky, by methods largely automatic, using a camera of only one inch aperture. This camera is able to cover the entire area of the northern night sky in two successive nights. The photographs secured in this manner are cataloged and filed for future reference. This collection of photographs may fairly be described as the Harvard written history of the night sky. The value of this collection of photographs has been demonstrated on many occasions. When the extraordinarily brilliant new star in *Aquila* was discovered on June 8, 1918, astronomers desired to know the earlier history of this star. Three decades of this history were written in the Harvard photographic files. A reference to this history disclosed that the new star had existed as a variable star of approximately the tenth magnitude during these decades, and that its rise from the tenth magnitude to approximate equality with *Sirius* on June 9th had taken place in a few days preceding the date of discovery. Other applications of the Harvard history to especially interesting astronomical problems are equally noteworthy.

Professor Pickering was greatly beloved at home and by astronomers everywhere, and his innate kindness and consideration had much to do with his success. Recognition and honors came to him in great numbers and from high places. Six American universities and two European universities conferred doctor's degrees upon him, and he was a Knight of the Order Pour le Mérite. He was an honorary member of the leading national societies of Great Britain, France, Germany, Ireland, Italy, Mexico, Russia, and Sweden, and of many of the more special societies. He was awarded the Henry Draper Gold Medal of the National Academy of Sciences, the Rumford Gold Medal of the American Academy of Arts and Sciences, the Bruce Gold Medal of the Astronomical Society of the Pacific, and he had the distinction of receiving the Gold Medal of the Royal Astronomical Society on two occasions. It is probable that the expression of confidence which gave him greatest satisfaction, and certainly the highest expression of the esteem in which he was held by his American colleagues, consisted in his annual re-election as President of the American Astronomical Society from 1905 to the time of his death.

W. W. CAMPBELL.

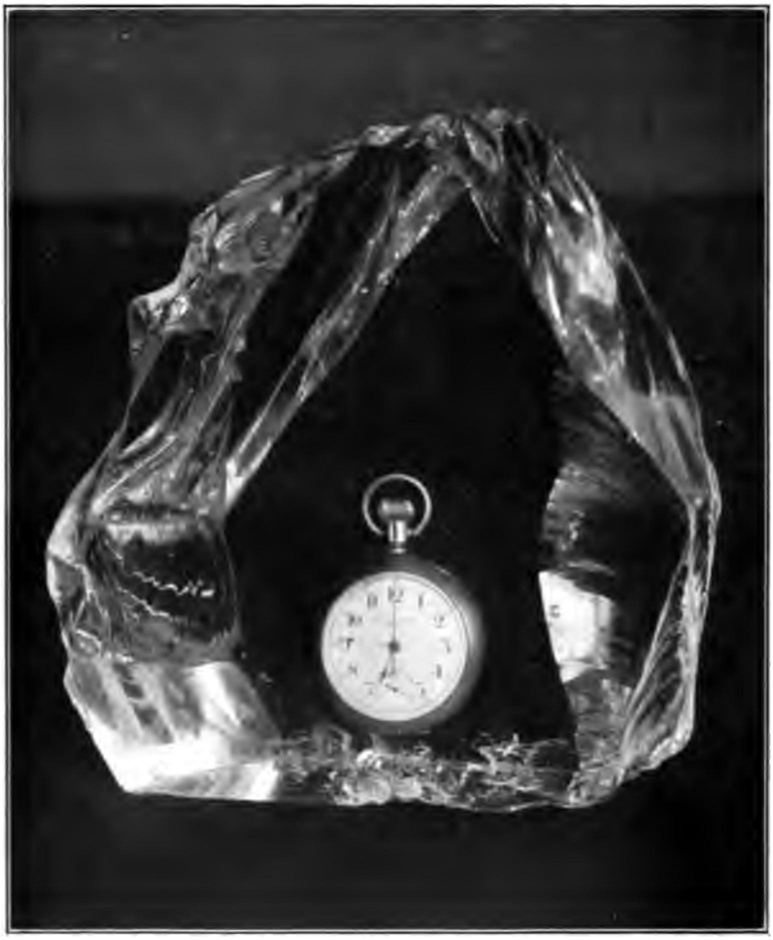

PLATE IV. A 13-pound piece of medium flint optical glass, made by the Pittsburgh Laboratory of the Bureau of Standards. Two faces have been polished for inspection; the watch is seen thru four inches of glass.

OPTICAL GLASS

By Heber D. Curtis

The astronomer, whether professional or amateur, is apt to have a rather vague idea of the extent to which optical glass is used outside of the lenses and prisms of his own instruments. Most amateurs know that two sorts of optical glass, crown and flint, are needed for their telescope objectives, and have read of the difficulties inherent in securing disks of a size and perfection adequate for the lenses of giant telescopes. It may be mentioned here that nineteen failures were experienced before the disk for the flint lens was obtained for the objective of the Lick 36-inch refractor.

The point which many do not adequately appreciate is the fact that the telescope lens, while the most difficult to obtain in the larger sizes, is one of the least of the modern applications of optical glass. Every binocular, every camera, every microscope, or any other instrument of precision thru which light must pass, requires its quota of a substance which differs from ordinary glass almost as much as does the diamond from graphite; both of the latter are carbon, and the optical and the ordinary sorts are both glass, but there the resemblance ends.

When we pass from the needs of peace to the requirements of a nation waging modern scientific war, optical glass changes from a mere essential of the observatory or the laboratory to an element nearly as indispensable as the high explosive. Binoculars, and excellent ones, are needed in vast numbers in all branches of the military service. It would not be advisable, even with peace at last assured, to state the enormous number of high-grade binoculars which were being made every week at the time of the signing of the armistice. These, in turn, formed but a small part of the total consumption of optical glass for war purposes. The number and the complexity of the optical devices in use on a modern dreadnaught would surprise a physicist. The army requires an equally bewildering array. Gun sights, bore-sighting devices, tank sights, range-finders, periscopes, bombing sights, airplane cameras, and many other types of optical instruments requiring lenses and prisms of high optical quality, are needed for war, not by scores, but by thousands and tens of thousands.

Prior to August, 1914, practically all our optical glass came from a few German, English and French makers. There were some secrets in the industry, but the total annual world demand amounted to only a hundred tons or so. No American firms had cared to go to the expense involved in satisfying this demand, which is relatively very small, from the standpoint of the tonnage of the commercial glass manufacturer. One large optical firm had started to make optical glass for its own use.

The war at once cut off the German supply, and practically all the English and French product was requisitioned by these nations for their own extensive military needs. The United States had been absolutely dependent upon these foreign sources of supply, and our government found itself suddenly faced by the necessity of creating its own optical glass industry. The same conditions existed in many other lines where the war later found us entirely unprepared. Before we could furnish any glass for the needs of science and industry, we must first make the glass.

That the cutting off of the supply of optical glass threatened to have very serious consequences was at once recognized by many. Several manufacturers started work on the problem. The Bureau of Standards at once began research work in this field, setting up its experimental furnace and auxiliary apparatus in its Pittsburgh plant in the winter of 1914. This experimental work was pushed vigorously, and the Bureau installed its first one thousand pound pot in the winter of 1910. It is found difficult to "experiment" on proportions and ingredients when only small amounts are melted; something can be told as to the nature of the product, but the deductions as to the actual value and quality of the glass are apt to be at fault.

This pioneer work proved of great value. We must first understand, however, something more of the manufacture of optical glass, in order that we may realize certain of the difficulties of the problem. I shall reserve for the last portion of this paper a brief résumé of the various sorts of optical glass.

Optical glass is not easy to make. The ingredients, carefully selected as regards purity, properly ground and mixed, are melted in large pots holding from five hundred to a thousand pounds or more. The furnace temperature must be very carefully controlled; if too low, the bubbles will not rise and disappear; if too high, portions of the pot will dissolve. The melted glass must be thoroly stirred to make it as homogeneous as possible. The stirring rod itself, and some small portion of the pot wall, will melt and dissolve in the glass; hence these must not contain any substance which will color or stain the glass. When, after long and careful cooling, the fused block is cooled, and the pot is broken from around the glass, all portions near the pot wall are found to be contaminated by the pot material and worthless for optical purposes. The blocks and fragments from the central portions are then carefully inspected to determine their value. To be suitable for high-grade lenses and prisms the glass must be of high homogeneity and transparency, it must be almost completely free from small bubbles and contain no "stones," it must have very few or no "striae," and it must be free from internal strains. These exceedingly rigorous requirements bring it about that, on the average, only about twenty per cent of a very successful melt is of sufficiently high quality to render it usable. The satisfactory blocks and fragments from the central portions of the pot will be worth from four to six dollars per pound,. and it is doubtful whether much profit can be made at these prices. Frequently these selected rough pieces are heated almost to the melting point and pressed in moulds into convenient slabs or disks.

Many difficulties were met at the start and gradually overcome by the Bureau experts. One of these was the finding of a suitable refractory material for the pots. This was finally found in the waste bisque of white-ware potteries. It formerly took a long while to produce a pot by hand work. A method of casting the pots was developed which cut down this time to three weeks. The pot material must be practically free from any iron oxide; more than 0.02 per cent of this will tend to discolor the glass.

At the time of the declaration of war between the United States and Germany considerable progress had been made. Some success had been attained by the Bausch and Lomb Company, Keuffel and Esser, the Spencer Lens Company, and the Pittsburgh Plate Glass Company. The Bureau of Standards had made some very good glass, but its capacity was small. There was need, at once, for very much larger quantities of optical glass to meet the requirements of the army and navy, or of the optical firms who were desirous of taking contracts for the instruments needed by these services. Conferences were held, and it was realized that energetic measures must be taken at once for a great expansion of the small optical glass industry. In this work many agencies co-operated.

The Bureau of Standards at once enlarged its Pittsburgh plant, and placed at the disposal of all interested the results of its preliminary experimental work in this field. The glass manufacturers provided enlarged facilities. The Geophysical Laboratory of the Carnegie Institution sent experts to the optical glass factory of the Bureau of Standards and to the Bausch and Lomb plant, studied the methods which had been developed, and gave valuable assistance in the analysis of materials and product, the procuring of pure materials and the development of inspection methods. A valuable method for quickly testing and inspecting the rough blocks by immersion in a tank filled with liquid of the same refractive index as the glass was developed by Mr. Taylor of the Bureau of Standards' Laboratory at Pittsburgh, and is now in use by several firms. It greatly expedites the preliminary inspection of the glass, by obviating the necessity, which formerly existed, of polishing or rough-grinding surfaces to make possible the examination of the glass for striae and other defects. A very large variety of useful optical glasses is known, but it was found not only possible, but advisable in the emergency, to limit the types manufactured to a few, not more than eight or ten.

It is a pleasure to state that the emergency was successfully met, and that optical glass of excellent quality was soon being made in quantities sufficient to meet the multifarious needs of our army and navy. The total production was probably in the neighborhood of twenty tons per month. The Bureau of Standards Laboratory at Pittsburgh, running eight single-pot furnaces, had nearly reached its planned capacity of two tons of optical glass per month at the time the armistice was signed. Most of this went to the Navy Optical Shop Annex at Rochester, where the navy made its own optical parts for many of its instruments; a smaller amount was sent to the Bureau shops at Washington, where it was used for the needs of the Bureau and for various experimental purposes. The views which illustrate this article are in all cases, except the binocular striae, of optical parts made of Bureau of Standards glass.

I wish that the limits of this article and considerations of military expediency would permit a complete description of the war activities of the Bureau of Standards, of which its services to the optical glass industry form but one item. In times of peace, a busy place engaged in scientific and industrial researches nearly as numerous

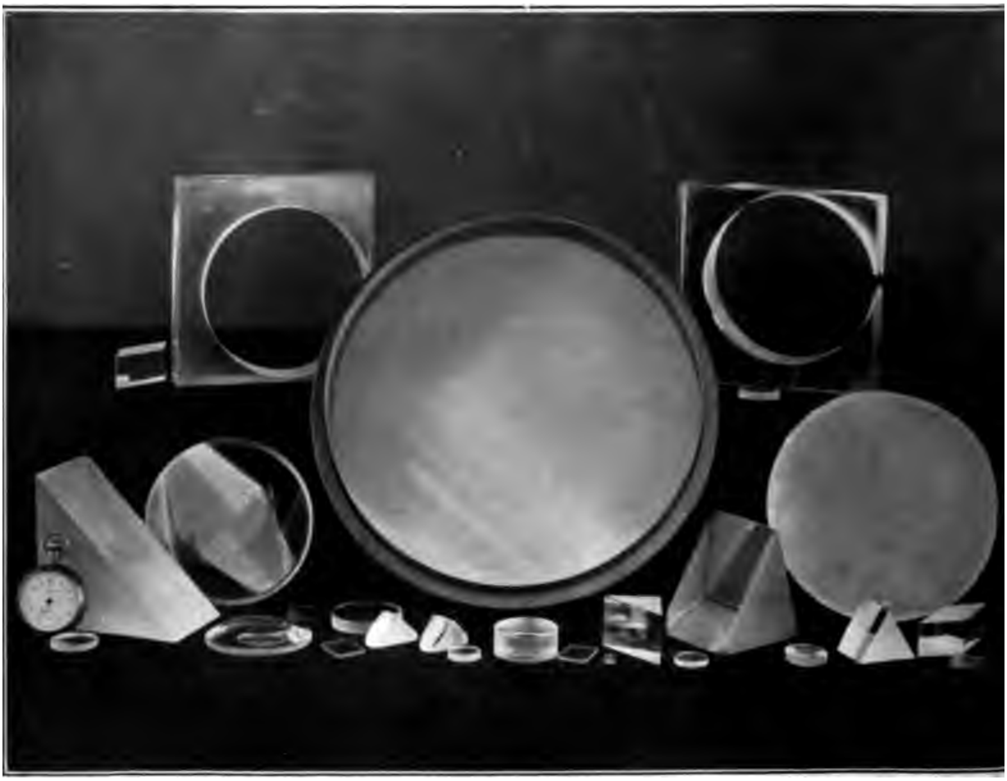

PLATE V. Finished optical parts made at the Bureau of Standards from Bureau of Standards optical glass.

The 12-inch flat, the two large prisms, the 5-inch doublet of 21 inches focal length, and the sextant mirrors were made by Mr. J. Clacey, the smaller prisms and lenses by Mr. F. C. Weaver, in the Bureau of Standards Optical Shop.

The two slabs from which the flint and crown lenses for the 5-inch lens were cut are seen on each side above. At the right is a rough-ground disk for a 6 inch lens.

as those of the combined physical and chemical laboratories of the universities of the country; under the stress of war, the Bureau perforce expanded into a personnel of nearly fifteen hundred, gathered from all over the United States, working and experimenting in every phase of the war's scientific needs. Dyes and chemicals for industry or fundamental science, methods of making ammonia, tests of recoil of great guns, airplane-wing design and testing in the Bureau wind-tunnel, tests of airplane and balloon fabrics and varnishes, tests of airplane motors (including, of course, the Liberty motor), improvements in aerial photography, design and testing of optical and other military instruments, testing of airplane instruments for recording height and speed, radio telegraphy and telephony, rating of time-pieces for the newly created merchant marine, assistance in the design of experimental apparatus for the army and navy—all these and many similar problems were attacked with success.

Glass, and especially optical glass, is a very complex material. Below are given the analyses of four optical glasses made by the Bureau of Standards; the first corresponds to the older ordinary flint, the last three belong to the "newer" types of glass containing boron and barium.

Substance	Dense Flint	Ordinary Crown	Boro.-sil. Crown	Barium Crown
SiO_2 (Silica)	39.0%	67.0%	64.2%	53.6%
Na_2O (Sodium monoxide)	3.0	12.0	9.4	1.7
K_2O (Potash)	4.0	5.0	8.3	8.3
B_2O_3 (Boron trioxide)	....	3.5	11.0	2.7
BaO (Barium oxide)	....	10.6	6.1	14.3
ZnO (Zinc oxide)	....	1.5	....	2.5
As_2O_3 (Arsenic trioxide)	....	0.4	0.4	....
CaO (Calcium oxide)	4.0	....	1.0	....
PbO (Lead oxide)	49.0	....	....	16.7

The revised list of Jena optical glasses given in Hovestadt[1] comprises sixty-eight varieties. The amateur may ask—Why are there different kinds of optical glass, and why are so many sorts needed?

The answer to this question takes us into the realm of geometrical optics, and, to be treated with any completeness, would involve more technicalities than would be permissible in a popular article. A very brief outline of the application of optical glass in lens design will, however, be of interest.

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[1] Hovestadt, "Jena Glass and its Scientific and Industrial Applications," translated by J. D. and A. Everett.

A lens is a piece of glass (sometimes of other transparent substances) bounded by spherical or very nearly spherical surfaces. Light is bent from its initial direction, or refracted, when it passes the boundary surface between two media of different composition. The measure of this bending, known as the index of refraction, is defined mathematically as the ratio of the sines of the angles which the ray of light makes with a perpendicular to the refracting surface before and after passing the surface. The reason for the refraction is that light passes thru different media at different speeds; it is really the ratio of the speed of light in air to that in the glass which is given by this quantity, the refractive index. The refractive index differs for different sorts of glass, and in the same glass it varies with the wave-length or color of the light; blue light is refracted or bent more than red light.

In a camera, telescope, or similar optical instrument, we would like to have a lens or combination of lenses which would unite every ray, of every color, proceeding from a given point of the object, precisely into the corresponding point of the image. It can be proven mathematically that there is no lens, nor any possible combination of lenses or shapes of lens surfaces which will do this with *absolute* accuracy. It is the aim of the lens designer, however, to attempt to get as close to the desired perfection as he can by properly proportioning the curves of his lenses, their respective thicknesses, the distances between the different lenses, and the refractive powers of the sorts of glass used.

While much can be found out as to the magnitude of the various errors or aberrations of a lens system, in a general way, by mathematical analysis, the final proportions of a compound lens of high quality are to be found only by "cut and try" methods in the optical shop, or by tedious trigonometrical calculations. In these calculations the lens designer traces the paths of different rays, of different colors, thru all the surfaces of a lens system, and determines how well the rays from a point of the object can be united in the corresponding point of the image. If the performance is not satisfactory, some or all of the dimensions of the lens system are varied, and the rays traced thru again.

> "At first sight it seems a remarkable thing that a system of surfaces bound by the simplest of all known curves, namely, the circle, with their centers on a common axis, should give rise to problems which, *if solved to a high degree of exactitude*, are of such extraordinary complexity."—(Taylor, *A System of Applied Optics*, page 5).

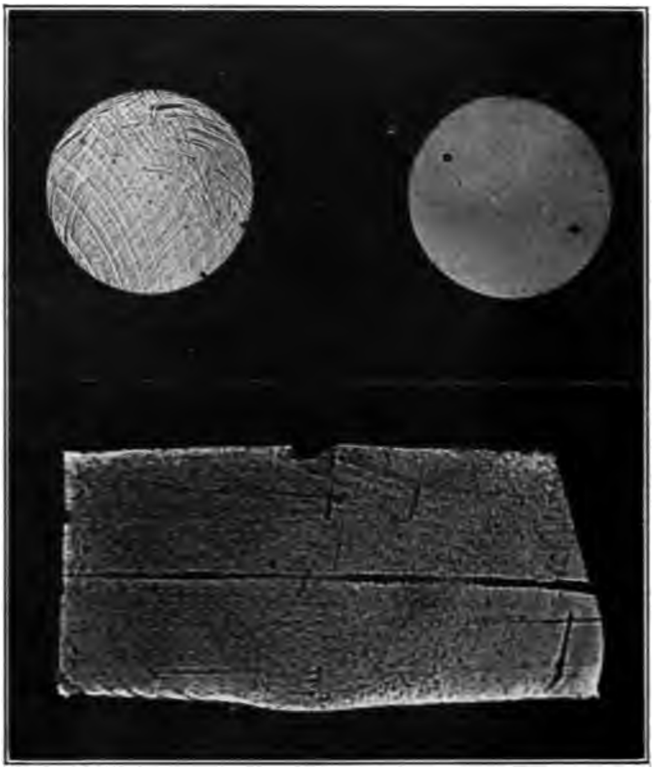

Plate VI. Striae in a piece of optical glass and in the lenses of a binocular.

A reasonably perfect modern camera lens is generally the work of many men, both as to the design and the manufacture. It is said that merely the design of the first Zeiss Tessar camera lens involved months of work by four skilled and many routine computers, and cost in the neighborhood of 30,000 marks.

Your camera lens, then, is not a simple shape of one sort of optical glass. It consists of from four to eight carefully shaped and proportioned lenses, composed of at least two sorts of optical glass. A good microscope objective will frequently have as many as ten separate small lenses, of different glasses and curvatures, some of which are cemented together and others not.

A *single* lens with spherical bounding surfaces will be of very limited usefulness as a telescope or camera lens. It will be afflicted with spherical aberration (light from different zones of the lens fails to come to a single focus); chromatic aberration (light of different colors will not come to the same focus); astigmatism (horizontal and vertical lines off the axis can not be brought to the same focus); coma (rays making an angle with the axis will meet in a comet-like image instead of in a point); and other errors. If the focal length be very great compared with the aperture of the lens, and the field of view small, most of these errors will not be very noticeable, and for this reason many of the earliest telescopes were made very long.

If now, for a telescope objective, we combine two lenses, one of crown glass (refractive index usually from 1.50 to 1.55), and one of flint glass (generally characterized by containing lead oxide, and having refractive indices from 1.56 to 1.65 or higher), many of these errors, notably the chromatic aberration, can be greatly reduced. In particular, with the older sorts of flint and crown glasses, we can make a telescope lens which will bring to the same focus two different colors of the spectrum, thus getting rid of a good deal of the chromatic aberration. If we choose the two colors for which we correct the objective in the green and the yellow, the visual region, we shall have a very good telescope lens, tho there will be a fringe of purple around the edges of bright objects, due to the neglected red and violet rays. This peripheral color effect troubles the astronomer very little. However, the first thing which the average visitor says on looking thru the Lick telescope at some bright object like *Jupiter* is—"What a beautiful purple color!" and is at some pains to comprehend the attendant astronomer's explanation that this color does not belong to the planet at all, but is an effect due to the telescope itself.

There is actually more than three inches between the points where the yellow and the violet rays are brought to their foci in the Lick refractor.

Up to about 1888 the optician had only the usual crown and flint glasses at his disposal. It was at this time that the experiments of the Schotts, with the assistance of the firm of Zeiss and liberal subventions from the German government, resulted in the discovery of new types of glass which have made possible great improvements in lens design. Too much credit can scarcely be given these investigators for these improvements.

In addition to the six elements occurring in the older types of optical glass, namely, silicon, potassium, sodium, lead, calcium, and oxygen, the Schotts tried twenty-eight other elements in varying proportions up to at least ten per cent of the whole. Of these new ingredients, which were tested in varying proportions and in many experimental melts, boron and barium proved perhaps of the greatest importance. In addition to the refractive index of a glass, there is a quantity known as its "dispersion," or the relation existing between the refractive indices of the glass for different colors, which is of the highest importance in removing or diminishing the many aberrations to which a system of lenses is subject. This dispersion factor is ordinarily indicated by the Greek letter ν, and is defined by the formula:

$$\frac{n_D - 1}{n_F - n_C} = \nu$$

In the above formula

n_D = refractive index for light of wave-length 5893
n_F = " " " " " " 4861
n_C = " " " " " " 6563

In the older glasses this factor decreased with the increase in the refractive index in different glasses; in the "new" optical glasses the values of this dispersion factor for the flints and crowns are made more nearly equal. A few typical values are given here.

Glass	n_D	ν
[illegible] Light Dense Flint [illegible]	[illegible]	34.4
[illegible] Ordinary Crown [illegible]	[illegible]	50.6
[illegible] Flint [illegible]	[illegible]	40.4
[illegible] Barium Crown [illegible]	[illegible]	55.1

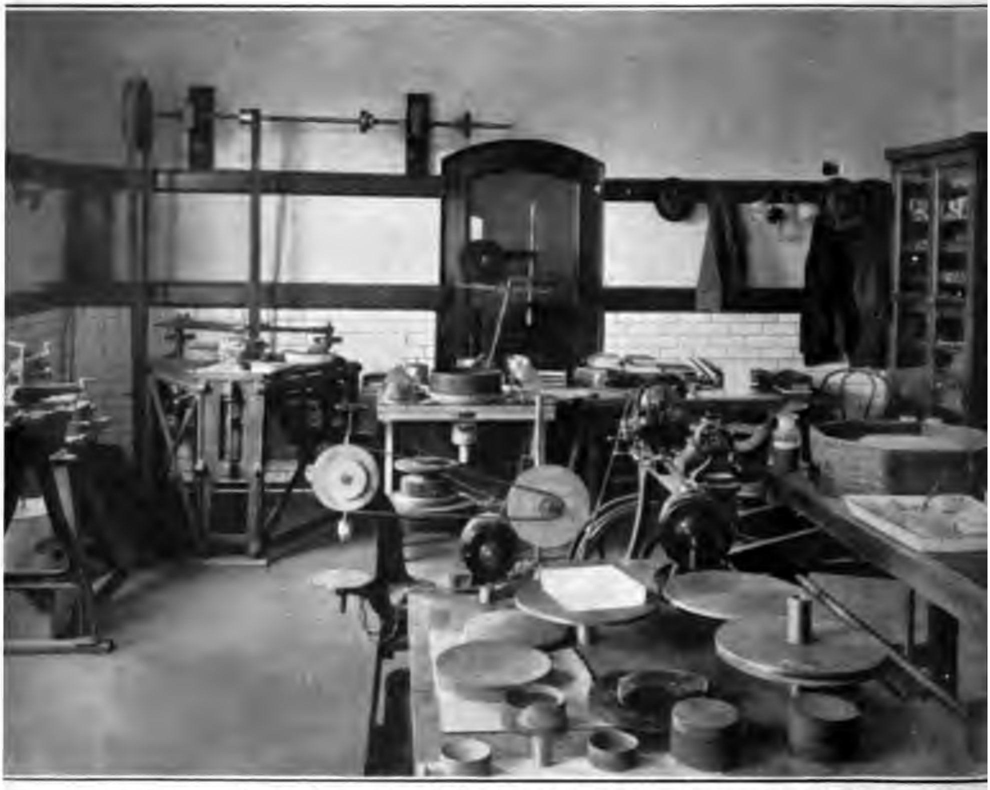

PLATE VII. A view of a portion of the Optical Shop of the Bureau of Standards.

This peculiarity of the dispersions of the "new" or Jena glasses has made possible the correction of the chromatic aberration of a telescope lens for *three* separate colors, instead of for *two* colors, as with the older types of glasses, and has thus greatly reduced the amount of uncorrected color in such objectives. They have also proved of very great value in the design of modern photographic lenses.

Previous to the outbreak of the European war, later to become a world war, the optical glass industry was entirely European. We have sketched, necessarily in briefest outline, the work which has been done to bring this into the category of American industries. There is still a wide field for further experimentation, and the Bureau of Standards will certainly continue this phase of its activities.

What of the future of this industry in the United States? Here commercial and financial considerations will undoubtedly prove of paramount importance. At least two of the firms at present manufacturing optical glass propose to continue in the field; several others, which have engaged in the work to assist in meeting war needs, will cease manufacture soon. There is little profit in this product, and some patriotism will have to be combined with the profit or loss of the balance sheet. It is not, and never will be, a very large industry, important as it is for the scientific independence of the country. We are making in America as good optical glass as that of any foreign firm. Can those firms which will continue in the production of American optical glass meet the post-war competition of foreign cheaper production? This is a matter for the earnest consideration of those who desire to see this country self-contained and independent in this essential and important industry. It appears certain that this country should never again be permitted to become entirely dependent upon foreign optical glass; we can and will make our own.

THE PARALLAX OF THE ORION NEBULA

By William H. Pickering

In *Harvard Circular*, **205**, the writer obtained the value 0".0005 for the parallax of this object. In *Contributions of the Mount Wilson Solar Observatory*, **147**, 62, just published, Professor Kapteyn obtains the value 0".0054 ±0".0009. Since both results were deduced by practically the same method, that of comparing the brightness of the stars associated with the nebula, with the brightness of stars of the same types, whose distance was assumed to be known, it is a matter of interest to determine why such divergent results should have been obtained. The explanation is twofold—different data and different constants.

Professor Kapteyn used only the brightest stars in the nebula, those whose type was known with the greatest certainty, and extending down to magnitude 9.5. He selected from these the magnitude which appeared to him to represent the greatest number of stars, and based his result on this magnitude. Two determinations were made, one using the stars of spectral classes B0 to B5, and the other stars of spectral classes B8 to B9.

The writer based his results on an investigation, *H. A.*, **32**, 36, in which he had measured the photographic magnitudes of something over 800 stars in the nebula and its immediate vicinity, and compared them with earlier visual magnitudes measured by G. P. Bond. Certain necessary corrections were applied to Bond's measures, and the stars were then divided into two groups, those that were brighter photographically than visually, and those that were fainter. The former were called blue stars, and the latter white. In *Circular*, **205**, he showed that there was a well-defined cluster associated with the nebula, but that this cluster contained few white stars below magnitude 15, and few blue ones below magnitude 14. In short, the cluster came to an end at this point. We had reached and passed the limiting magnitude, and no more stars were likely to be discovered in it by an increase of telescopic power. Any stars added would be merely superposed upon it from outside regions.

While the types of these fainter stars were not known with the same accuracy as those of the brighter ones, on which they were based, the investigation had the advantage that the data were complete, and a slight error in the assumed type should make no great difference in the resulting parallax. Instead of selecting by examination what seemed to be the most prevalent type, the writer took the mean magnitude of all the blue stars, some seventy in number, that were clearly associated with the nebula. Herein lay the chief difference in the methods of the two investigators. As a result, the writer obtained an appreciably fainter magnitude than Professor Kapteyn, which is one reason why the latter's value for the parallax is larger.

With regard to the constants employed, the earlier investigation labored under a certain disadvantage, because while the writer employed the best values obtainable at the time, yet since it was published, new values differing very materially from the older ones have been found, which are probably more accurate. This difference is so serious that the writer has decided to re-determine his value of the parallax, employing exclusively the new values of the constants. The type of spectrum which he selected for his blue stars was B2. This type, according to the data and formula given by Russell, *Popular Astronomy*, 1914, **22**, 331, corresponds to an absolute magnitude of -1.0. According to Kapteyn's just published work, above mentioned, page 84, this type would correspond more nearly to an absolute magnitude of $+1.0$. A diminution of two magnitudes would of itself increase the resulting parallax 2.5 times.

Of sixty stars in the constellation of *Orion* belonging to types O and B, ninety per cent were of type B3, and bluer. For this reason we selected type B2 for the blue stars. According to a table published by Kapteyn, page 58, based on recently determined but unpublished Harvard results, it appears that the fainter stars of type B are redder than the brighter ones, which is indeed not unnatural. The blue star of average brightness in the nebula is of magnitude 10.5. An inspection of the table leads to the conclusion that the average blue star of this brightness is probably of type B7, but can hardly be bluer than type A. The absolute magnitude of the average star of type B7, by interpolation, according to Kapteyn, is $+2.0$. This is three magnitudes or sixteen times fainter than the value obtained from our earlier constants, and increases the earlier value of the parallax four times, to $0''.0020$. The corresponding distance would be 50 dekaparsecs, or 1600 light years. The actual reduction is made by means of the formula $m-M=5 \log d$, where m and M are the apparent and absolute magnitudes 10.5 and 2.0, respectively, and d the distance in dekaparsecs. It is useless to attempt to furnish a value based on the white stars or a resulting probable error in a case like this, where the values adopted depend so largely on estimates. The best we can do, perhaps, is to judge that the error is not likely to exceed 0″.0010. A probable error attached to what is in any case ultimately an estimate, a matter of judgment, leaves on the mind of the reader an impression of accuracy which is often in no wise justified by the facts.

A striking feature of this region of the heavens is the great range in the absolute magnitude of the stars of type B. The photometric difference in magnitude between β *Orionis* and its companion, distance 9″.1, according to *H. A.*, **64**, 167, is 6.32. β is therefore 337 times as bright. The photographic brightness of the fifth and sixth stars in the trapezium of the great nebula was found to be 9.4 and 9.0. Unless they are redder than their brighter components their visual magnitudes must be 9.8 and 9.4. Burnham describes them both as 11.0, which would make them very blue indeed. Even if they are no fainter than 10, the range between them and ι *Orionis*, which is clearly connected with the nebula, as shown in *Circular*, **205**, is seven magnitudes, or 625 times. Extending the range down to the faintest blue stars connected with the nebula, which we may assume to be of magnitude 13.5, gives us a difference of 10.5 magnitudes, or 16,000 times, and if we include β *Orionis*, magnitude +0.3, which Kapteyn places but slightly nearer to the Sun, and which therefore becomes six times brighter than ι, we have a total range of 100,000. There are few types of stars which show so great a range of brightness as type B. It is therefore important that as many stars as possible should be included in any investigation of the distance of this type.

With a parallax of 0″.0020 the value of $m-M$ is, as we have seen, 8.5 magnitudes. Similarly with Kapteyn's parallax of 0″.0054 the difference is 6.3. The apparent magnitude of ι *Orionis* is 2.9. Its absolute magnitude assuming a parallax of 0″.0020 is consequently −5.6. Since the absolute magnitude of the Sun is +4.8, we find that the luminosity of ι is 14,500, and of β 87,000, the Sun's luminosity being taken as the unit. According to Kapteyn these values would be 1,900 and 11,400.

While all of these figures are strikingly large, we can judge of the plausibility of a parallax more satisfactorily by means of the minimum values, since the maximum possible brightness of a star, especially in the case of an object such as the *Orion* nebula is necessarily very uncertain. If we consider the faintest blue stars in the nebula to be of magnitude 13.5, then their absolute magnitude with parallax 0".0020 will be +5.0, or about the same as that of our Sun. According to Russell, *Pop. Astr.*, 1914, **22**, 339, the surface brightness of a star of type B7 would be nine times that of our solar unit, and its density about one-tenth as great. Therefore their diameters must be one-third that of the Sun, and their masses one three-hundredth, or about four times that of *Jupiter*. With Kapteyn's parallax the masses would be reduced twenty times more. These figures are strikingly small.

It may be that Russell's values of the absolute magnitude of the stars of types A and B are not quite so far out of the way as Kapteyn's results would seem to imply, and that by increasing the parallax from 0".0005 to 0".0020 we may have brought the nebula rather too near us, but it certainly seems unlikely that it should be nearer still, and that these stars should be still smaller.

There seems to be only one way of avoiding the difficulty of supposing all the bright stars of *Orion* to be supergiants, and that is to assume that all the fainter blue stars are really somewhat reddish. If we assume those of magnitude 10.5 to be dwarfs, of type A7, and absolute magnitudes 5.2, this will permit us to adopt as large a parallax as 0".0054. In that case we must remember that there is a considerable body of blue stars outside of the region that we have considered, but obviously connected with the nebula, besides the thirty-five blue stars within it, that are fainter than magnitude 10.5. Some of these are as faint at least as magnitude 13.5, and must be redder than type A7. Besides these there is a great mass of white stars, some still fainter, yet which are clearly associated with the nebula. These must be redder still—probably of types G and K. We are not in the habit of associating dwarfs of these types with nebulae, and particularly with one capable at the same time of producing such stars as those of types Oe5 and B0. Yet this seems to be the only alternative if we wish to adopt a large parallax such as Kapteyn's for the nebula, and refuse to believe it possible for a star to be 100,000 times as bright as our Sun. It is clear that this question can only be satisfactorily settled when a reliable determination of the types of these fainter stars has been made.

In this connection it may be mentioned that Shapley has pointed out, accepting Kapteyn's value of the parallax, that of the "one hundred stars within two or three degrees of the trapezium that are supposed to be definitely variable, nearly all are fainter than the fourteenth magnitude at maximum," so that "the average absolute brightness at maximum is only about a tenth that of the Sun, and at minimum less than a twentieth. Apparently they are dwarfs, while all other variable stars—Cepheids, eclipsing binaries, long-period variables (at maximum)—are typically objects of high luminosity." *Contributions from the Mount Wilson Solar Observatory*, **156**, 12. Indeed it would seem from one point of view, that the *Orion* nebula must be the place of very small things.

With a parallax of 0".0054 the absolute magnitude of these variables at maximum is only 7.7. With a parallax of 0".0020 their absolute magnitude is 5.5, still a little fainter than the Sun. If the writer has erred in the constants that he has adopted in this second determination of the parallax, he believes it is on the side of bringing the nebula too near us, rather than of making it too remote. The luminosity of the stars, if altered, should be made greater, rather than less, and the true value of the parallax made to lie between 0".0005 and 0".0020, depending on the value of the constants that we decide to adopt. We will, however, temporarily accept Kapteyn's constants, and call the value of the parallax 0".0020, but we must consider this figure to be a maximum value. In closing this paper it may be pointed out that the parallax first assigned to this object by the writer, some twenty-five years ago, based on the proper motions of nineteen stars associated with it, *H. A.*, **32**, 80, of 0".003, lies between his last value and that of Kapteyn.

Mandeville, Jamaica.
February 18, 1919.

ON THE RELATION OF THE DOPPLER EFFECT TO KIRCHHOFF'S LAW

BY LUIS RODES, S. J.
Observatorio del Ebro, Spain

With such an abundance of literature concerning the so-called "Doppler effect" and Kirchhoff's law in spectral analysis, attention has been paid mainly, and I should say only, to the displacement of the lines, resulting from any *change in the optical path connecting the source of light or the absorbing medium with the observer.* Even in books so complete and of such great authority as the "Traité d'Optique" by Mascart, one reads in Volume III, page 92, "Le résultat ne dépend que de le vitesse relative de l'astre et de l'observateur," a statement which is indeed true if applied to the position of emission lines of the spectrum, but which *does not contain the whole truth,* inasmuch as emission lines can be modified by the relative velocity between the source of light and the absorbing medium independently of the velocity with respect to the observer.

I arrived at this conclusion by considering the relation between Kirchhoff's law and the Doppler-Fizeau effect. The former has been announced as absolutely establishing that a cooler gas absorbs the vibrations of light having the same period or the same wavelength as those emitted by itself when radiating; and H. Fizeau (*Annales de Chimie et de Physique,* **19,** 211, 1870) gave scientific accuracy to Doppler's statement, showing that the effect of a high velocity between the source of light and the observer, would be not the change in color but the displacement of the spectral lines, due to the apparent change in the period with which they reach the observer. Hence just as the refraction and interferences are *functions of the relative period* with which the vibrations arrive at the instrument, *so also will the absorption correspond to the relative period with which the vibrations reach the absorbing gas.*

As a direct consequence of this relation, we could have a layer of cooler sodium vapor, which if moving fast enough, would not absorb at all the two yellow lines of the sodium flame. In general if a gas A, emitting vibrations of absolute period p_o moves with a velocity v with respect to the source of light, then the original absolute period of the vibrations absorbed by it, will be given by the equation $p_x = p_0 \left\{1 \mp \frac{x}{c}\right\}$, c being the velocity of light and x being determined by the condition equation $p_0\left\{1 \mp \frac{x}{c}\right\}\left\{1 \pm \frac{v}{c}\right\} = p_0$, from which, neglecting the term of second order $-\frac{xv}{c^2}$, we get $x = v$ and $p_x = p_0 \left\{1 \mp \frac{v}{c}\right\}$. I have found nothing about the subject in current text-books on optics, such as Drude, Preston, Wood, Schuster, etc., or in those dealing more specifically with spectrum analysis applied to astronomy, as for instance, "Spectroscopie Astronomique," by P. Salet, Paris 1909. It was only in a remarkable monograph, "Das Dopplersche Princip," by Dr. H. Konen in Bonn and published as Chapter VII in the second volume of H. Kayser's "Handbuch der Spectroscopie" that I discovered a hint of my own conclusion.

Curiously enough, Van der Willigen, probably the first to whom the idea occurred that a cooler gas if in motion would not absorb the same vibrations as when it is at rest, held this conclusion as "étrange" and used it as an irrefutable argument against Doppler's principle, as shown in his work, "Sur la fausseté de la proposition que les refractions des rayons lumineux est modifiée par le movement de la source lumineuse et du prisme," to which Konen refers.

One could have hoped that Konen would discuss fully the matter in his thesis, but the way he answers Van der Willigen's argument, that if the above conclusion were true, we could not have the reversal of the bright lines in the solar spectrum, shows that even Konen himself did not pay much attention to the subject. He simply answers that Van der Willigen did not consider that in the case of the Sun, the photosphere and the reversing layer are relatively at rest. This does not seem to be the proper answer, however, because even if the absorbing layer were moving as a whole, the absorption lines would appear the same, with their *relative positions* unchanged, altho the absorbed vibrations of the continuous spectrum would be different. A little further on and in a half-page paragraph (the monograph has about one hundred pages) Konen touches again on the matter and points out the consequence that sodium vapor, if moving fast enough, would not absorb the bright lines characteristic of this element. He adds also that "möglicher Weise, würden sich derartige Vorgange unter Umständen in Sonnenspectrum zeigen" without coming to any application.

Altho when I found this statement, the analysis I submit below was already written, I am glad to be able to give now this reference and to recommend Konen's monograph as perhaps the most complete treatise ever published on Doppler's effect.

It is not my intention to study theoretically the causes that can modify the optical path of the vibrations and their apparent period, nor to discuss the influence that the absolute movement of the source of light, the observer and the medium thru which the vibrations are travelling, may have on their behavior; that has been practically exhausted by Mascart, "Traité d'Optique," Kayser, Konen, Drude and many others. It is enough to say that the effect of all the causes that can change the path of the vibrations between the source of light or the absorbing medium, and the observer, must also be considered on the optical path connecting the source of the light and the absorbing element. W. Michelson's formula (*Astroph. Jour.*, **13**, 192, 1901),

$$N = n\left[1 - \frac{1}{v}\Sigma\left(l\frac{d\mu}{dt} + \mu\frac{dl}{dt}\right)\right],$$

giving the apparent period N with which the vibrations reach the observer as a function of their original period n and the change in the optical path due to the relative velocity $\frac{dl}{dt}$, between the source of light and the observer as well as to the change in refractive index $\frac{d\mu}{dt}$ in the medium, can have special application in our case.

What I intend in the following pages is to present, from the practical point of view of astrophysics, and in the most simple way, the effect that the velocity of the absorbing element with respect to the source of light can have on the absolute period of the vibrations absorbed and on the resulting changes on the structure of the discontinuous spectrum, and connect these changes with those due to velocity with respect to the observer which are considered in the ordinary application of Doppler's effect.

In order to find a general expression for all possible cases connecting *the original absolute period of the vibrations absorbed, the absolute period of the vibrations emitted by the absorbing element,* and *the relative period with which they reach the observer* (which determines their position in the spectrum), let us call S the source of light, A the absorbing element, E the observer.

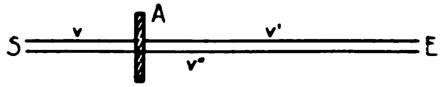

FIG. 1

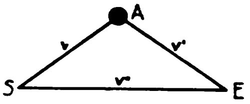

FIG. 2

Let p_x be the original absolute period of the vibrations absorbed,
p'_x be the relative period with which they arrive at the absorbing element A.
p_o be the absolute period of the vibrations emitted by the absorbing element A.
p'_o be the relative period with which vibrations of absolute period p_o coming directly from the source of light reach the observer.
p''_x be the relative period with which vibrations of absolute period p_x reach the observer.
v be the absolute value of the velocity of A with respect to S.
v' be the absolute value of the velocity of A with respect to E.
v'' be the absolute value of the velocity of S with respect to E.

Then remembering equations

$$p_x = p_o\left(1 \mp \frac{x}{c}\right)$$

$$p'_x = p_x\left(1 \pm \frac{v}{c}\right) = p_o\left(1 \mp \frac{x}{c}\right)\left(1 \pm \frac{v}{c}\right) = p_o,$$

we shall have, if c is the velocity of light,

$$p''_x = p'_x\left(1 \mp \frac{v'}{c}\right) = p_x\left(1 \pm \frac{v}{c}\right)\left(1 \mp \frac{v'}{c}\right) =$$

$$p_o\left(1 \mp \frac{x}{c}\right)\left(1 \pm \frac{v}{c}\right)\left(1 \mp \frac{v'}{c}\right) = p_o\left(1 \mp \frac{v'}{c}\right) \qquad \text{I}$$

$$p'_o = p_o\left(1 \mp \frac{v''}{c}\right)$$

All possible values of v, v', and v'' will correspond to one of the following cases:

(1) $v = 0$, $v' = 0$, $v'' = 0$, giving

$$p_x = p'_x = p''_x = p_o$$

(2) $v \neq 0$, $v' \neq 0$, $v'' = 0$, giving

$$p_x\left(1 \pm \frac{v}{c}\right)\left(1 \mp \frac{v'}{c}\right) = p'_x\left(1 \mp \frac{v'}{c}\right) = p''_x = p_o\left(1 \mp \frac{v'}{c}\right)$$

(3) $v = 0$, $v' \neq 0$, $v'' = 0$, giving

$$p_x\left(1 \mp \frac{v'}{c}\right) = p'_x\left(1 \mp \frac{v'}{c}\right) = p''_x = p_o\left(1 \mp \frac{v'}{c}\right)$$

and $p'_o = p_o$

$$\left.\begin{array}{ll}
(4) & v \neq o,\ v' = o,\ v'' \neq o, \text{ giving} \\
 & p_x\left(1 \pm \frac{v}{c}\right) = p'_x = p''_x = p_o \\
(5) & v = o,\ v' \neq o,\ v'' \neq o, \text{ giving} \\
 & p_x\left(1 \mp \frac{v'}{c}\right) = p'_x\left(1 \mp \frac{v'}{c}\right) = p''_x = p_o\left(1 \mp \frac{v'}{c}\right) \\
(6) & v \neq o,\ v' \neq o,\ v'' \neq o, \text{ giving} \\
 & p_x\left(1 \pm \frac{v}{c}\right)\left(1 \mp \frac{v'}{c}\right) = p'_x\left(1 \mp \frac{v'}{c}\right) = p''_x = p_o\left(1 \mp \frac{v'}{c}\right)
\end{array}\right\} \begin{array}{c} \text{and} \\ p'_o = p_o\left(1 \mp \frac{v''}{c}\right) \end{array}$$

First Case. In the first case the vibrations absorbed will be of the same period p_o corresponding to element A, and they cannot reach the observer without their intensity being affected by the absorbing medium; the absorption lines will occupy in the spectrum their normal position corresponding to vibrations of period p_o on the Earth.

Second Case. In the second case, which represents an absorbing medium moving between the source of light and the observer, as would be the case if vapors were projected from, or falling on, a central luminous mass, p_x cannot be equal to p_o, and therefore *emission lines due to element A can reach the observer unaffected* by the absorption of the same element if v is great enough to produce a displacement equal to the width of the line; otherwise either one of the edges of the lines can be affected according to the direction of the movement.

The main consequence of this case is that we can have *emission and absorption lines* due to the same element A; their *relative separation*, which must increase with the wave length, will be a *function* of the *velocity* with which the absorbing vapor moves with *respect to the source of light;* the emission lines from S would occupy their normal positions, v'' being zero.

Another consequence is that some lines due to an element or elements A could disappear, being absorbed by a moving element B different from the one which emits the lines. That will happen whenever there is an emission line, the corresponding period p_x of which satisfies the relation $p_x\left(1 \pm \frac{v}{c}\right) = p_o$. If the element A had vibrations of absolute periods p_o, p_1, p_2, etc., and the absorbing layer contains elements emitting vibrations of absolute period p_x, p_y, p_z, some of which satisfy the relations $p_x\left(1 \pm \frac{v}{c}\right) = p_o$, $p_y\left(1 \pm \frac{v}{c}\right) = p_1$, $p_z\left(1 \pm \frac{v}{c}\right) = p_2$, then only the emission lines for which these relations are satisfied would be absorbed or affected by the absorbing medium, the others remaining unchanged. The vibrations absorbed will reach the observer with a relative period $p''_x = p_0 \left(1 \mp \frac{v'}{c}\right)$, which fixes the position of the absorption lines in the spectrum as compared with the normal position for lines of absolute period p_0 due to element A.

In the ordinary cases indicated by Fig. 1, if $v'' = 0$ we shall have also $v' = v$ in absolute value, and then neglecting terms of the second order, we get from equation (1)

$$p_x = p''_x = p_0 \left(1 \mp \frac{v'}{c}\right),$$

showing that the absolute period p_x of the vibrations absorbed by the moving element A equals the relative period with which they reach the observer and is given by $p_0 \left(1 \mp \frac{v'}{c}\right)$, in accordance with the Doppler effect. Using the full formula as given by Michelson, we see that even for $v'' = 0$ and $v' = v$ we could have $p_x \neq p''_x$, or a difference between the original absolute period of the vibrations absorbed, and the apparent period with which they reach the observer, if the change in the optical path between the source of light and the absorbing element, were due also to terms of the form $\frac{d\mu}{dt}$, *as must happen in the case of a continuous eruptive protuberance.*

In some special cases, as in comparing the direct spectrum of the Sun with the spectrum of its light as reflected by a comet (Fig. 2), we could have $v'' = 0$ and $v' \neq v$, if the comet, surrounded by absorbing gases, were moving with different relative velocity with respect to the Sun and Earth; in such a case the constitution of the Sun's light as passing thru the comet's atmosphere would be affected by v, changing the intensity of some of the lines and possibly adding new sets of absorption lines due to elements common in the Sun's and the comet's absorbing medium.

Let us take for instance the cyanogen absorption bands *as constituted in the solar spectrum;* if they correspond to vibrations of absolute period p_0, then the relative period with which they arrive at the cyanogen of the comet will be $p_0 \left(1 \pm \frac{v}{c}\right)$, and consequently they will not be affected by the latter, which will instead absorb from the solar spectrum vibrations of period $p_x = p_0 \left(1 \mp \frac{x}{c}\right)$,* reaching the comet with a relative period $p'_x = p_0 \left(1 \mp \frac{x}{c}\right) \left(1 \pm \frac{v}{c}\right) = p_0$; hence a new absorption line arises separated from the one due to the Sun's atmosphere by a distance which will be a function of the difference in periods p_0 and $p_0 \left(1 \pm \frac{v}{c}\right)$, no matter what might be the velocity of v', which will *shift all the lines as a whole.* We shall have in our case, if the velocity v'' (Sun-Earth) is zero, an absorption line in the direct spectrum of the Sun occupying its normal position corresponding to vibrations of period p_0, but, on the solar spectrum as coming from the comet, *two absorption lines,* the position of which will correspond to the relative periods $p_0 \left(1 \pm \frac{v}{c}\right) \left(1 \mp \frac{v'}{c}\right)$ and $p_0 \left(1 \mp \frac{v'}{c}\right)$, with which they reach the observer. The velocities must be taken with the positive or negative sign, according as their effect is to increase or shorten the distance between the points to which they refer.

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* When dealing with the effect of a second absorbing medium, as in the case of reflected light, P_x stands for the period of vibrations as emerging from the first absorbing layer on the Sun.

It may also be worth while to remark that even for a given value of v', the distance between the double absorption lines of the same element can vary, due to the factor $\left(1 \pm \frac{v}{c}\right)$, the effect of which is to shift the solar line, as viewed thru the comet's atmosphere, to either side of the line produced by the latter. This affords a means for distinguishing between the lines due to the reflecting body and the ones due to the original source of light.

Different sets of absorption lines due to the same element A could also appear in the spectrum of the stars, whenever on their surfaces were great masses of the element A, as eruptive protuberances, moving with radial velocities v_1, v_2, v_3, etc., each of which would absorb from the continuous spectrum, vibrations of different absolute period given by the formula $p_x = p_0 \left(1 \pm \frac{x}{c}\right)$, where x stands approximately for v_1, v_2, v_3, etc. Since the light of the entire disk of the star passes thru the slit, it is evident that portions of the spectrum corresponding to vibrations with those absolute periods which have been absorbed in some regions of the stellar surface, cannot have the same intensity as the portions corresponding to vibrations which have not been absorbed in any region at all; hence if the protuberances should extend over sufficiently great regions and the difference in velocities were such as to produce a displacement greater than the *width* of the line, we would get faint and commonly narrow separated lines in triplets or in pairs due to the same element A.

The spectrum of the solar light as reflected by the planets can also be considered in this second case, more on account of their rotation than on account of the radial velocities with respect to the Sun caused by the eccentricity of their orbits. It was pointed out by H. Deslandres in a communication to the Academy of Sciences in Paris (*C. R.*, **120,** 420, 1895), that "lorsqu'un corps est éclaré par diffusion, sa lumière subit le déplacement non seulement par rapport à l'observateur, mais aussi par rapport à la source"; and in a note to this communication, H. Poincaré gave the formula $\tau\left[1+\frac{1}{c}\left(\frac{dR}{dt}+\frac{dR'}{dt}\right)\right]$ connecting the absolute period of the vibrations absorbed with the apparent period with which they reach the observer when reflected by the planet; this formula becomes identical with the one given independently in the present article, $p_0\left(1\pm\frac{v}{c}\right)\left(1\mp\frac{v'}{c}\right)$ if we put $\frac{dR}{dt}=v$ and $\frac{dR'}{dt}=v'$. As shown by J. E. Keeler (*Astroph. Jour.*, **1,** 352, 1895), the fact had been announced before, altho not with the conciseness and exactitude of Poincaré. Since then this matter has been fully discussed theoretically, and subsequently applied by different astronomers to the rotation of the planets. But here again attention has been focussed on the displacement and inclination of the lines more than on their nature and character, which depend on the relative velocity v of the observed region of the planet with respect to the Sun. An important consequence from the present point of view is that if there are elements common to the Sun's and the planet's atmospheres, their lines will coincide whenever $v = 0$, and that in all other cases *v will widen and possibly double the common lines.*

When observing *Jupiter's* east limb in opposition, the vibrations absorbed by the Sun's atmosphere with a period p_0, corresponding to the element A, would reach the observer with a relative period $p_0\left(1-\frac{12}{c}\right)\left(1-\frac{12}{c}\right)$ equal approximately to $p_0\left(1-\frac{24}{c}\right)$, while the apparent period of the vibrations absorbed by the same element of the planet, would be $p_0\left(1-\frac{12}{c}\right)$, giving a difference of relative period equal to $p_0\,\frac{12}{c}$, equivalent to a displacement of about 0.2 Å at $\lambda = 5000$ Å; with high dispersion this would be enough to separate narrow lines. Hence the most favorable conditions to detect an element common to the Sun and planet would be to observe the latter in those regions of the disk or in those places in their orbits for which v is a maximum and compare the observations with those for which v is a minimum. Let me indicate here that the further away the planet observed is, the greater will be the effect of the rotation on the broadening of the lines; the reason is that with the same width of slit, the region of the planet which reflects the light is greater, and hence v and v' can vary between wider limits.

Third Case. $v = 0$, $v' \neq 0$, $v'' = 0$. As has already been indicated, these conditions can be fulfilled in nature when observing the spectrum of the Sun's light as reflected by a planet or a satellite at the time and on the region for which v, the velocity with respect to the Sun, is zero. In such a case, both the planet's and the Sun's lines due to a common element A, will arrive at the observer with the same apparent period and consequently they will occupy the same position in the spectrum; ***the absorption lines will be reinforced but not separated or resolved***, and, if compared with the lines of the direct spectrum of the Sun, all will show a shift due to the difference in periods p_0 and $p_0\left(1 \mp \frac{v'}{c}\right)$ between the direct and reflected vibrations.

Fourth Case. $v \neq 0$, $v' = 0$, $v'' \neq 0$. This is the case of an observer surrounded by an atmosphere in motion with respect to the source of light. The terrestrial absorption lines of the element A will occupy in the spectrum a normal position corresponding to vibrations of absolute period p_0, which has not been changed; but, according to the equation, p_1 or the period of the vibrations absorbed from the solar spectrum, will not be the same as p_0, the period of element A in the observer's atmosphere; hence the lines cannot coincide and their separation will be a function of v or of v'', which, except for purely theoretical cases in the movement of the reflecting bodies, will be equal to v. That brings the case under the common application of Doppler's effect. In brief, the apparent period of the solar lines will be $p_0\left(1 \mp \frac{v}{c}\right)$ and that of the terrestrial lines p_0; when observing the center of the solar disk at noon v would represent the radial velocity of the Earth with respect to the Sun, which can fluctuate between ± 0.50 km. approximately. ***Emission lines*** of an extra-terrestrial origin and corresponding to an absolute period ***p_0 can reach the observer*** with the apparent period $p_0\left(1 \mp \frac{v}{c}\right)$.

Fifth Case. $v = 0, v' \neq 0, v'' \neq 0$. This is the case of a source of light surrounded by a quiet atmosphere moving as a whole with respect to the observer. As shown by the general formula applied to this hypothesis, $p_x = p_0$, and *emission lines* of absolute period p_0 due to an element *A cannot reach the observer* unaffected by its presence in the absorbing medium; they will be absorbed independently of v' and v''. If these velocities are equal, as will be the case when observing direct light, then equations $p''_x = p_0\left(1 \mp \frac{v'}{c}\right) = p_0\left(1 \mp \frac{v''}{c}\right) = p'_0$ show, in accordance with Doppler's effect, that all emission as well as absorption lines will be shifted from their normal positions by a quantity given by the difference in period p_0 and $p_0\left(1 \mp \frac{v''}{c}\right)$. If among the different periods of the vibrations emitted by the source of light, there are some given by $\frac{p_0}{1 \mp \frac{v''}{c}}$, then the relative period with which they would reach the observer, will be p_0, producing a line occupying the normal position of one due to element A, and which might be wrongly attributed to it.

Observing the Sun's light as reflected by a planet, we could have $v = 0$ and $v' \neq v'' \neq 0$. In such a case, the lines common to the Sun and the planet (or possibly to a comet) would coincide as in the third case; all the lines would be shifted from their normal positions by an amount given by the difference p_0 and $p_0\left(1 \mp \frac{v'}{c}\right)$, and if they are compared with the lines of the direct spectrum of the Sun, the displacement will be given by the difference in relative periods $p_0\left(1 \mp \frac{v''}{c}\right)$ and $p_0\left(1 \mp \frac{v'}{c}\right)$ between the direct and reflected vibrations.

Sixth Case. $v \neq 0, v' \neq 0, v'' \neq 0$ and $v \neq v' \neq v''$. These conditions can be fulfilled if a source of light is surrounded by an atmosphere, moving in a radial direction from or towards the center, and the whole having a relative velocity with respect to the observer. Here, as in the second case, *emission lines due to the element A can reach the observer*, and their separation from the absorption lines due to the same element will be given by the difference in their corresponding relative periods $p_0\left(1 \mp \frac{v''}{c}\right)$ and $p_0\left(1 \mp \frac{v'}{c}\right)$. The same expressions give also the displacement of both kind of lines as compared with the normal position due to the lines of the element A.

All the statements under second case for reflected light can be repeated here, with the only difference that the position of the lines in the direct spectrum will correspond to their relative periods $p_0\left(1 \mp \frac{v''}{c}\right)$.

Altho it is not my object to discuss the spectrograms of novae, it may be permitted to indicate some facts which according to my opinion could be explained with the preceding analysis in view:

(*a*) The presence in the spectrum of novae of emission and absorption lines due to the same element.

(*b*) The fact that these absorption lines have appeared double and even sometimes triple. (Cf. "Ueber das Spectrum der Nova Geminorum," Nr. 2, by Furnhjelm, *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, Nr. 68, 1913.)

(*c*) The fact that the absorption lines are always displaced towards the violet, at least on their first appearance, and that their relative displacements, as well as the displacements with respect to the emission lines, are proportional to the wave-length, as pointed out by various observers.

(*d*) Finally, the fact that the lines show such instability in character, seems to give weight to the assumption that we are dealing with conditions considered in the Second or the Sixth Case, to which we refer the reader.

It is true that there remains the difficulty in conceiving such high velocities as are necessary to produce shifts of over 20 A, as in the case of the absorption lines with greatest displacement; but considering: *first*, the immense proportions of the catastrophe which must take place in a nova in order to increase the intensity of its light a hundred thousand times within a few days; and *secondly*, that it is not necessary to attribute the velocity to the star as a whole (the movement of which is probably given by the displacement of the emission lines or by the narrow absorption lines H and K), but to great masses of vapor only; and *thirdly*, that even on our quiet Sun we have witnessed protuberances projected with a velocity of hundreds of kilometers per second, it does not appear so improbable that the great displacements in the absorption lines of the spectrum of novae may be due to great masses of vapor moving in radial directions from the center. The difficulty emphasized by Plaskett that "the absorbing hydrogen would have two different velocities, 1675 and 2360 kil/sec, at the same time" can be avoided by assuming that *they take place in different regions of the visible stellar surface*. If the reflection of light plays any rôle, as Seeliger and Kapteyn have suggested, then the velocities could be decreased by a considerable amount, altho not more than one-half for the most favorable conditions.

The preceding analysis may have also an application to the spectra of planetary nebulae and to the variability of bright hydrogen lines for some stars, in so far as the movement, in a radial direction, of the outer layer in a mass of radiating elements, would naturally increase the brightness of the emission lines; the reason is that in this case the relative period p'_0 of the vibrations absorbed by the cooler gases of the periphery, would not be equal to p_0, the absolute period of the vibrations emitted by the inner and hotter gases of the same elements.

Mount Wilson Observatory,
January 14, 1919.

CHARLES LEANDER DOOLITTLE

On the first day of March there passed on to high reward a distinguished astronomer and a lovable man. Astronomy of precision has long been indebted to the tireless energy and the painstaking exactness with which Professor Doolittle carried on his latitude observations. These were begun with very inadequate equipment, before the epoch of Dr. Chandler's investigations of the variation of latitude. The instruments used later at the Flower Observatory were of the most perfect construction, but the entire series of results for the Sayre Observatory at South Bethlehem as well as at the later station near Philadelphia were of the highest excellence. Probably no single contribution to the problem of the latitude variation was of greater value.

The zenith telescope has been the most efficient instrument for tracing by differential observations the very minute quantities involved, tho the contribution from meridian circle observations of a fundamental character must be taken as the basis of the problem. The zenith telescope first used by Professor Doolittle was one that had been virtually discarded by the United States. Coast and Geodetic Survey, and had been purchased for service in the instruction of the engineering classes at Lehigh University in practical field astronomy. In addition to comparatively arduous duties in teaching mathematics and astronomy, the observations of latitude were begun as a piece of research work that would be well within his unaided resources, and a possible contribution to science. The first results led him to suspect a secular variation in the latitude of his station. Later discussion of these same observations confirmed the results of the work of Dr. Chandler, mainly based upon meridian circle observations up to that date. Those results, it may be remarked, were not at once accepted unanimously by the profession, and were sometimes classed as entirely "empirical" in the nature of the terms included. Of course Dr. Chandler willingly accepted the challenge offered by the use of this word; his constants were empirical ones precisely, as he sought for them in the only way by which an unprejudiced investigator would attack the puzzling and apparently conflicting mass of data existing at that time. The current observations for following the accepted variations of latitude are planned with this definite object in view, and it is not easy for the observers of this year following the war to realize how blind the way to a solution then appeared to be. Those early observations at the Sayre

Observatory show well what can be done with comparatively imperfect apparatus handled by a careful and expert observer.

Born in 1843, Professor Doolittle received his astronomical training under that master of the science, Professor James C. Watson, at the University of Michigan. With one of his classmates, O. S. Wilson, later Superintendent of the New York State Survey, he abandoned his college studies to enlist in the Civil War. It was only after an interval of some years that he was able to return for graduation in 1874, with the degree of C.E. He served on topographical work with the United States Northern Boundary Commission in this interval, along with Professor Lewis Boss, who was making the astronomical observations. For at least part of one winter he lived under canvas amid the extreme rigors of that northern climate.

He was appointed Professor of Mathematics and Astronomy at Lehigh in 1875, and remained there twenty years. He then accepted the similar chair at the University of Pennsylvania, which he held up to the time of his retirement from active work, having been succeeded by his second son, Eric Doolittle. The older son, Charles, has also followed his father's profession as a member of the staff of the Nautical Almanac office at Washington. My own entrance at Lehigh was of the same date (1875), but I did not come under the direct instruction of Professor Doolittle until my junior year. His oldest son was later a student of mine in 1883. Our Society on this coast had the pleasure of having Professor Doolittle and his wife with us at the meeting combined with that of the American Astronomical Society, at Berkeley, in 1915.

Professor Doolittle was twice married, his first wife dying in his first year at Bethlehem. His widow, Helen Wolle Doolittle, was born there. Two of his sons served in the war just closed by armistice, one of whom, Captain Gilbert Doolittle, was killed in France, in September last. The other, Ensign Melvin Doolittle, is still in our service. Four sons and a daughter survive.

Professor Doolittle has been buried at Nisky Hill cemetery, Bethlehem, a beautiful site overlooking the rapid river named to carry on the traditions of the early days of the Indians, so successfully converted at the old Moravian settlement. He was a man of singularly modest temperament, genial in manner and straightforward in character. These qualities were recognized by his students—one of the real tests of a man—as they have been by a wide circle of friends. R. H. TUCKER.

March 20, 1919.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1919

BY MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME[1]

First Quarter... May	6,	3^h34^m P.M.	First Quarter... June	5,	12^h24^m A.M.
Full Moon...... "	14,	5 1 P.M.	Full Moon..... "	13,	8 28 A.M.
Last Quarter.... "	22,	2 4 P.M.	Last Quarter... "	20,	9 33 P.M.
New Moon..... "	29,	5 12 A.M.	New Moon.... "	27,	12 53 P.M.

The first of the three eclipses of the year is a *Total Eclipse of the Sun* on May 29th. The line of totality runs from the Pacific just off the west coast of South America thru Peru, Bolivia, and Brazil, crossing the Atlantic and the Gulf of Guinea, entering Africa at Cape Palmas and ending at sunset just off the east coast of Africa. It will not be visible at all in North America except as a partial eclipse of very small magnitude in Central America, and not at all in Europe or Asia except in extreme southwestern Arabia. The most noticeable feature will be the unusual duration of totality—nearly seven minutes as it crosses the Atlantic. The principal cause of the great duration is the fact that the Moon passes its perigee and is nearest the Earth about a day before the eclipse, thus making its apparent diameter nearly a maximum; also the Earth is nearly at its greatest distance from the Sun, making the Sun's apparent diameter nearly the least possible.

The Sun reaches the summer solstice and summer begins at about 4 A. M., June 22nd, Pacific Time.

Mercury is a morning star thruout May, coming to greatest west elongation on May 5th; but altho the elongation is a large one, nearly 27°, there is less than an hour's interval between the rising of the planet and of the Sun on account of the fact that the planet is much farther south than the Sun. Superior conjunction is reached on June 11th, and *Mercury* becomes an evening star. By the end of the month the planet is well out toward greatest east elongation, and remains above the horizon nearly an hour and a half after sunset. The conditions for visibility are then very good. There will be rather a close conjunction between *Mercury* and *Jupiter* on June 26th, the latter 1°38′ south.

Venus is an evening star, setting about three hours after sunset up to the middle of June. After this the interval shortens up a little, altho the maximum apparent distance from the Sun is not attained until July 4th. The shortening on account of the more southerly declination of the planet counts more in the interval between setting of Sun and planet than the increase in apparent distance. There is a rather close conjunction of *Venus* and *Jupiter* on May 25th, the former passing the latter about 2° to the north.

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[1] The phenomena are all recorded in Pacific Standard Time. To reduce to the present "Daylight Saving Time" add one hour.

Mars is too near the Sun for naked eye view for the whole two months' period except possibly for the last days of June. It comes to conjunction with the Sun on May 9th, and will be a morning star until its next opposition, April 21, 1920; but altho it will soon move far enough away from the Sun so that it can be easily seen in the early morning, it will not begin to brighten up materially until nearly the close of the year. Its maximum distance from the Earth is reached in June, and will be about 233 millions of miles.

Jupiter is still in fair position for observation in the western sky in the evening but is drawing closer to the Sun. On May 1st it does not set until about five hours after sunset, and on June 30th only about one hour. It is, however, so bright that it will not be a difficult object up to the end of the month. It moves eastward about 10° in *Gemini*, and toward the end of June it is south of *Castor* and *Pollux*, about the same distance from the nearer one as the stars are apart. On June 25th it is about 2° south of *Venus*.

Saturn is also an evening star in the southwestern evening sky, following rather less than two hours after *Jupiter*. On May 1st it sets about two hours after midnight, and on June 30th about two hours before midnight. The planet is in the constellation *Leo* and moves about 4° eastward and southward toward *Regulus*, (*Alpha Leonis*), and at the end of June is less than 3° west of the star. As seen in the telescope the minor axis of the ring seems to be gradually diminishing, being less than one-fourth of the major. As the minor axis of the rings shortens we are looking at the plane of the rings more and more obliquely, the apparent total area of the rings diminishes, and the light from the rings grows less, so that in the summer the whole system of planet and rings sends us only a little more than half the light it did during the early spring.

Uranus is now a morning object, rising on May 1st a little less than three hours before sunrise and on June 30th about three hours after sunset, so that it is getting into a fair position for naked eye view. It is nearly stationary in the constellation *Aquarius* near its western border, moving slowly eastward until June 6th, and then moving westward, but the whole motion is only a small fraction of a degree. There is no moderately bright star near, by which the planet may be easily identified.

Neptune is in the western sky in the evening in the constellation *Cancer*, not far from the cluster *Praesepe*, but of course can not be seen without a telescope.

PASADENA MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC

The 1919 meeting of the Pacific Division of the American Association for the Advancement of Science will be held at Pasadena, from June 19th to June 22nd. Ten or more affiliated societies, including the Astronomical Society of the Pacific, will meet with the Division.

The Astronomical Society plans to hold two sessions for the presentation of scientific papers, and the Physical Society, to which many of our members also belong, will hold at least one session. An excursion to the Mount Wilson Observatory is planned for Saturday afternoon and evening, and the 100-inch telescope will be open to inspection during the afternoon and, weather permitting, will be directed upon suitable objects during the evening. Members desiring to remain on the mountain over night can doubtless arrange for accommodations at the hotel, which is not very far from the Observatory. The laboratories at Pasadena will be open to members during the days of the meetings. A more detailed announcement will be made later.

The Committee on Program earnestly request that members presenting papers at this meeting send in abstracts to Dr. Harlow Shapley, chairman, not later than May 15th. The abstracts received will be printed in the June 10th number of these PUBLICATIONS. This procedure will stimulate discussion of the papers at the meeting, and no argument is necessary to show its desirability.

COMMITTEE ON PROGRAM.

(NINETY-THIRD) AWARD OF THE DONOHOE COMET-MEDAL

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. William Reid, of Rondebusch, South Africa, for the discovery of an unexpected comet on June 11, 1918.[1]

COMMITTEE ON THE COMET-MEDAL:
W. W. CAMPBELL,
J. H. MOORE,
STURLA EINARSSON.

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[1] A letter from Dr. Joseph Lunt, of the Royal Observatory, Cape of Good Hope, dated November 29, 1918, received February 8, 1919, brings much information concerning this comet. It was observed several times in South Africa, and provisional orbits were computed by Dr. Halm of the Cape Observatory, and by Mr. Wood of the Union Observatory. The Cape Observatory photographed the comet on twelve nights between June 15 and July 10, 1918.

To the best of our knowledge no information concerning this comet, except the original cable announcing the discovery, has hitherto appeared in print.

Note added March 18, 1919.—The orbit computed by Mr. Wood is printed in *Circular No. 43* of the Union Observatory (August 12, 1918), a copy of which has just been received.

NOTES FROM PACIFIC COAST OBSERVATORIES

SPECTRUM OF THE CRAB NEBULA

A spectrogram of this object, made between the dates November 5, 1918, and February 3, 1919, altho the result of forty-eight hours exposure is disappointingly weak. This is probably due in large part to the very bad seeing conditions that prevailed during eighty per cent of the exposure time. It seems worth while, however, to state the following points, which appear to be borne out by this spectrogram.

1. The spectrum is continuous, crossed by bright lines.

2. The light is made up of relatively more continuous spectrum for the brightest part of the nebula than for the other portions adjacent to it. The maximum intensity or effective wave-length of this continuous spectrum is about λ4600. It is too weak to give any clue as to spectral type.

3. The bright lines, at the point where they record their maximum intensity, have the following wave-lengths (uncorrected for radial velocity):

λ3719, 3748, 4681, 4948, 4995, 5036.

Other lines were also measured, but because of their weakness are not included. Giving weights to the first, third, fourth, and fifth, according to their quality, a radial velocity of −600 km/sec is found. This refers to a point about 55″ west of the center. Approximately the same distance to the east, the third and fifth line in the above list (the first and fourth could not be measured) give in round numbers a radial velocity of −1000 km/sec. The last line in the list shares in the greater shift to the violet at this point in the nebula.

If wave-lengths of the two lines λ3748 and λ5036 are corrected for an assumed radial velocity of −600 km/sec, they turn out to be λ3755 and λ5048. Wright's list of bright nebular lines contains none possible of identification with these two. They fall close to two helium lines, which are, however, in different series, and among the faintest lines in their respective series; and, furthermore, no other identifications with helium can be made. If we assume them to be the characteristic nebular lines λ3728 and λ5007 displaced to the red, their shifts would mean radial velocities of +1620 and +1750 km/sec, respectively, which in this case may be called good agreement with each other, considering the small dispersion and the fact that both lines lie outside the region of good focus.

4. Unfortunately, this spectrogram is too weak to justify any statement relative to the reality of a phenomenon similar to the Stark Effect, which Slipher evidently connects with the above apparently double lines.

R. F. SANFORD.

TWO NEW NOVAE IN THE ANDROMEDA NEBULA

Three half-hour exposures, made with the 60-inch reflector, one on January 4 and two on January 5, 1919, reveal two additional novae. These are numbered 12 and 13, numbers 10 and 11 having been reported in the December (1918) number of these PUBLICATIONS. Rough positions with reference to the nucleus and the approximate magnitudes are as follows for the second plate of January 5th.

No.	Co-ordinates		Magnitude
12	235″ N	85″ W	17.0
13	275″ S	220″ W	17.4

The exposure of January 4th was made under extremely bad seeing conditions and the plate cannot be used to determine variation of magnitude. It merely serves as an additional check upon the reality of the images. The first plate of January 5th is of poor quality, but number 12 certainly appears to be no brighter on it and may even be slightly fainter than on the following plate. Number 13 shows no change on the plates of January 5th. Number 12 is located in the patchy area which is so pronounced to the northwest of the nucleus. Number 13 is surrounded by the soft milky nebulosity along the major axis to the southwest of the nucleus.

Two similarly exposed plates were obtained on February 3, 1919. Number 12 is present on both plates and is estimated at about magnitude 17.3. Number 13 appears upon neither plate altho stars of the eighteenth magnitude are almost certainly present.

From the magnitude estimates made upon six novae in the Andromeda nebula, Nos. 2, 3, 4, 5, 6, and 10 (the others furnish no data), the rate of fall per day is found to average 0.05 of a magnitude. This is not at all inconsistent with the average rate for galactic novae. It will be seen that the change recorded for number 12 amounts to only about 0.01 of a magnitude per day, from which it might be inferred that its maximum magnitude was reached after January 5th.

R. F. SANFORD.

ON THE RELATIVE INTENSITY OF THE ABSORPTION LINES IN A SPECTROSCOPIC BINARY

Let S and S' be two stars the visible areas of which are A and A'. Let us call i and i' the photometric intensity of the continuous spectrum in the region corresponding to vibrations of period $p_x + \Delta_x$ proceeding directly from S and S' unaffected by the absorbing element E, and let us call ie, $i'e'$ the intensity for vibrations of period p_x, after they have been absorbed by E.

When the light of both stars is received on the slit, the total intensity I for vibrations of period $p_x + \Delta_x$ will be

$$I = Ai + A'i',$$

while the total intensity I' for vibrations of period p_x, in the case that both stars are at rest with respect to the observer, will be

$$I' = Aie + A'i'e'.$$

Hence the relative intensity of the common absorption line, corresponding to vibrations of period p_x, as compared with the intensity of the continuous spectrum in the neighboring regions, corresponding to vibrations of period $p_x + \Delta_x$, will be given by

$$\frac{I'}{I} = \frac{Aie + A'i'e'}{Ai \ + A'i_1},$$

and putting

$$\frac{Ai}{A'i'} = R,$$

$$\frac{I'}{I} = \frac{Re + e'}{R + 1} \qquad (1)$$

What the ratio must be in order to show a definite absorption line is a matter of photographic technique, depending on many material factors; it seems, however, that $I'/I = 9/10$, or any smaller value, may suffice.

If the two stars are moving with respect to the observer, with relative velocities v and v', the vibrations absorbed will not arrive with the same period and therefore they will not occupy the same place in the spectrum; hence the necessity of dealing with them individually.

Vibrations of period p_z will arrive at the observer, from S, with relative period $p_z\left(1 \pm \frac{v}{c}\right)$ and from S' with a relative period $p_z\left(1 \pm \frac{v'}{c}\right)$. Hence the total photometric intensity I'_1 in the spectral region corresponding to vibrations of period $p_z\left(1 \pm \frac{v}{c}\right)$, absorption line due to star S, will be Aie coming from S, and $A'i'$ coming from the continuous spectrum of S'; while the total photometric intensity I'_2 in the region corresponding to vibrations of period $p_z\left(1 \pm \frac{v'}{c}\right)$, absorption line due to star S', will be $A'i'e'$, plus Ai coming from the continuous spectrum of S. We shall have then

$$I'_1 = Aie + A'i'$$
$$I'_2 = A'i'e' + Ai$$

When the difference in period of vibrations $p_z\left(1 \pm \frac{v}{c}\right)$ and $p_z\left(1 \pm \frac{v'}{c}\right)$ is enough to separate the lines, the region corresponding to vibrations of relative periods $p_z + \Delta_z\left(1 \pm \frac{v}{c}\right)$ and $p_z + \Delta_z\left(1 \pm \frac{v'}{c}\right)$ will have a total intensity $I' = Ai + A'i'$, due to the fact that vibrations of these periods can reach the observer from both stars.

Hence we shall have for the absorption line due to S

and for S'

$$\left.\begin{aligned} \frac{I'_1}{I} &= \frac{Aie + A'i'}{Ai + A'i'} = \frac{Re + 1}{R + 1} \\ \frac{I'_2}{I} &= \frac{A'i'e' + Ai}{Ai + A'i'} = \frac{R + e'}{R + 1} \end{aligned}\right\} \qquad (2)$$

From these equations it can be seen that the intensity or rather the visibility of the absorption lines is a function not only of R but also of e and e'.

By comparing equations (1) and (2) it might be possible to deduce some important consequences regarding the existence and brightness of a companion star in cases where the oscillating absorption lines of a spectroscopic binary appear single.

If $R = 2.5$ and $e = e' = \frac{1}{4}$, the relative intensity of the common absorption line would be, according to (1),

$$\frac{I'}{I} = \frac{Re + e'}{R + 1} = \frac{3.5}{14},$$

while the relative intensity of each absorption line separately would be for S

$$\frac{I'_1}{I} = \frac{Re + 1}{R + 1} = \frac{6.5}{14},$$

and for S'

$$\frac{I'_2}{I}=\frac{R+e'}{R+1}=\frac{11}{14},$$

showing that the single absorption line should pass thru periodic changes in its relative intensity, if another component star contributes to the integrated spectrum. These periodic changes in intensity might be possible of measurement, even for the case where the single absorption line due to S' is too weak to be detected.

If $R=1$ and $e=\frac{1}{4}$, $e'=\frac{1}{8}$, we would get

$$\frac{I'}{I}=\frac{Re+e'}{R+1}=\frac{3}{16},$$

and for S

$$\frac{I'_1}{I}=\frac{Re+1}{R+1}=\frac{10}{16},$$

and for S'

$$\frac{I'_2}{I}=\frac{R+e'}{R+1}=\frac{9}{16}.$$

We may study by the same method the case of a single star, a considerable part of which is covered by an absorbing element E, thus reducing to ie the intensity of the vibrations of period p_x. In such a case, the total intensity I for the vibrations of period $p_x+\Delta_x$, coming unabsorbed from the entire stellar disk, will be given by

$$I=Ai,$$

while the total intensity I' for the vibrations of period p_x, absorbed in the area $A\alpha$ but not elsewhere, will be $I'=Ai\,(1-\alpha)+\alpha\, Aie=Ai\,(1+\alpha e-\alpha)$, and the relative intensity of the absorption line will be $I'/I=1+\alpha\,(e-1)$, giving

$$I'/I=7/10,\text{ for }\alpha=1/2.5\text{ and }e=\tfrac{1}{4},\text{ and}$$
$$I'/I=29/32,\text{ for }\alpha=\tfrac{1}{8}\text{ and }e=\tfrac{1}{4}.$$

If instead of having the element E in the area $A\alpha$ only, we should have it all over the surface of the star, in distinct masses moving with different radial velocities, for example v_1, v_2, v_3 in the areas $\alpha_1 A$, $\alpha_2 A$, $\alpha_3 A$, respectively, then we could have different absorption lines due to the same element, their relative intensities being

$$1+\alpha_1\,(e_1-1),\ 1+\alpha_2\,(e_2-1),\ 1+\alpha_3\,(e_3-1),$$

and their positions in the spectrum being a function of v'_1, v'_2, v'_3—a case which was considered, with possible applications to the spectra of novae, in my longer paper in this issue.

L. RODÉS, S. J.

SOLAR ECLIPSE NOTES

Professor Walter S. Harshman, formerly Superintendent of the American Nautical Almanac, has called my attention to a serious error in the charts published for the total solar eclipse of May 29, 1919, in both the American and the British Nautical Almanacs. The mathematical and charted data for this eclipse are precise duplicates in the two almanacs. The charts record the shadow band as passing thru the Gulf of Guinea, off the southwest coast of Africa, without touching the land bounding the gulf on the north. The fairly prominent landmark known as Cape Palmas is charted as lying entirely to the north of the eclipse path. This is in error. The coast line to the east and west of Cape Palmas is charted about two degrees of latitude north of where it really lies. The correct charting of this coast line places Cape Palmas very near the central line of the path.

Up to the present time the possibilities and promise of Cape Palmas and vicinity as a point of eclipse observation have been overlooked. The number of expeditions planning to observe the coming eclipse is apparently small. This is partly on account of the unsettled political conditions thruout the world and the difficulties and uncertainties of ocean transport arising therefrom, but also in great measure to the supposed unfavorable location of the shadow path. It is understood that the Cordòba Observatory of the Argentine Republic will dispatch an expedition to Brazil. The only other expeditions thus far announced are two from the British joint Permanent Eclipse Committee, one going to Sobral, Province of Ceara, Brazil, and the other to Princes Island, off the west coast of Africa. A note in an earlier number of these PUBLICATIONS called attention to the fact that the path crosses southern Peru, but very early in the morning, with the Sun too low for the making of favorable and accurate observations. The duration of totality in Brazil and West Africa is approximately five minutes. The maximum duration, which occurs near the mid-Atlantic, is nearly seven minutes.

Whether the availability of the Cape Palmas region will attract additional observers or change existing plans is not known. The eclipse date is too near to justify the sending of an American expedition to that point.

That so large an error in charting the north coast of the Gulf of Guinea should have occurred and remained undetected to date, is both surprising and unfortunate. We at Mount Hamilton charted carefully the eclipse path upon accurate maps of South America, but we took no interest in the path of the shadow across Africa.

The personnel of the British Expedition to Brazil will be Father Cortie of Stonyhurst Observatory, and Mr. Davidson of the Royal Observatory at Greenwich. The British Expedition to Princes Island will be in charge of Professor Eddington of Cambridge University, who will be assisted by Mr. Cottingham.

Both British expeditions will limit their activities largely to one problem, that of "weighing light"—in the language of Professor Eddington—in which the purpose is to observe and measure the so-called Einstein effect. According to certain hypotheses, light radiations possess mass and are subject to gravitational disturbance. If the hypothesis in one form or another represents the truth, then rays of light proceeding from stars which are seen very nearly in the direction of the Sun should be deflected from their straight line courses, as those rays pass close to the Sun and thru the Sun's gravitational field. If a ray of light coming from a star to the eclipse observer just grazes the edge of the Sun but without touching the Sun, it should be bent from its course in amount $0''.87$, according to one hypothesis, in twice this amount on another hypothesis, or not at all on a still different hypothesis. The eclipse of May 29th occurs with the Sun very favorably situated for the solution of this problem in the northern part of the *Hyades* cluster. A good number of stars in the photographic field, with the eclipsed Sun in the center, may be recorded with an exposure of ten seconds or less. Many eclipses will come and go before another will be so favorable in this regard. This is a condition encouraging to the dispatching of expeditions, but the weather conditions normal to Brazil and Princes Island late in May may fairly be said to be correspondingly discouraging. It is unfortunate that the travel conditions to these somewhat out-of-the-way stations are disturbed and uncertain.

Popular Astronomy for March, 1919, publishes the path of the total solar eclipse of September 10, 1923, both in mathematical terms and as a large scale map, a contribution from Director Gallo of the National Mexican Observatory at Tacubaya. The central line of the shadow path enters the west coast of Lower California at Todos Santos Bay, about fifty miles south of San Diego[1], California; passes about midway between Guaymos and Hermosillo on the Sonora railway; passes about midway between Torreon and Durango; enters the Gulf of Mexico about thirty miles south of Tampico; and enters the west coast of Yucatan about fifty miles south of Campeche. The eclipse in western Mexico will occur at approximately 2 P. M., and the duration will be about three and one half minutes of time. Professor Gallo promises a special publication concerning eclipse conditions in due time. It is to be hoped that he will be able to arrange for the making of weather observations at various points in or near the shadow path, during the first twenty days of September, 1919 to 1922 inclusive, *at the hour of the day when the eclipse will occur.* Weather observations made at the usual Weather Bureau hours of the morning and evening will have a certain value for eclipse observers, but what the observers really want to know are *the average conditions existing at 2 p. m. of September 10th.* These conditions may be extremely different from those of the morning and evening. The data supplied to prospective observers of the Russian eclipse of August 21, 1914, were based upon observations made in the morning and evening, and gave fair promise of clear skies for the eclipse. When the observers reached their stations in Russia they were surprised to find that, while the mornings, evenings, and nights were beautifully clear under settled weather conditions, the clouds began to form in the mid-forenoons and reached their maxima of almost complete cloudiness in the mid-afternoons, approximately at the eclipse hour. The Lick Observatory would not have sent an expedition to observe the Russian eclipse had we known of the existence of this diurnal factor of cloudiness, to which the published weather data had not referred. Similarly, the data prepared by the U. S. Weather Bureau for the guidance of prospective observers on June 8, 1918, in the State of Washington and elsewhere, having been based upon observations made at the Weather Bureau hours of morning and evening, failed to note the distressing fact that high winds developed in the middle of the day and reached their maximum strength at approximately the hour of the eclipse. These winds and the attendant dust storms were distressing to the bodies and souls of the astronomers, who had not known of these peculiarities.

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[1] According to Gallo, San Diego, California, is well within the shadow path.

It would seem that weather observations made at the time of the day that the eclipse is to occur promise vastly greater usefulness to intending observers than the usual observations made in the mornings and evenings.

W. W. Campbell.

Measures of Σ208 and Σ1834

The following measures may be of interest in connection with Professor Eric Doolittle's "Study of the Motions in Σ208, 10 *Arietis*, and in Σ1834," published in *Astron. Jour.*, **33**, 9 (February 13), 1919. Professor Doolittle's object was to determine whether the observations of these pairs could be represented on the theory that the relative motion in each was rectilinear; that is, that the components in each case were independent stars passing each other by virtue of their proper motions and not members of a binary system. He concludes that such representation is impossible and that each system is a binary. This was to be expected, and, so far as they go, my measures are confirmatory. The measures are:

		Σ208	
1915.829	112°.8	0″.38	1n 36-inch, "very difficult."
1916.951	117 .1	0 .35	1n 36-inch, "fair conditions."
		Σ1834	
1914.58	86°.0	0″.22	2n 36-inch, "good."
1916.38	87 .0	0 .28	2n 36-inch, "good."

If the motion in Σ1834 were rectilinear the companion should be in the third quadrant (266°.0 and 267°.0), and the residuals (O-C) for my measures of the two systems would be:

	Σ208	
	Δθ	Δρ
1915.83	− 7°.2	−0″.25
1916.95	− 8 .6	−0 .28
	Σ1834	
1914.58	−17°.3	−0″.20
1916.38	−17 .1	−0 .22

These are entirely too large to be attributed to error of observation. Moreover, on the best two nights, the following star in Σ1834 seemed to me the fainter, tho there is but little difference in the brightness of the components.

R. G. Aitken.

THE MOUNT WILSON OBSERVATORY

At the meeting of the Board of Trustees of the Carnegie Institution of Washington, held in Washington on Friday, December 13, 1918, "the name of the Mount Wilson Solar Observatory was changed to read 'Mount Wilson Observatory of the Carnegie Institution of Washington'."

PERSONALS

Mr. C. D. Shane, formerly Fellow in the Lick Observatory, who resigned in August, 1917, to engage in the service of the United States Shipping Board as instructor in navigation schools, has returned to his fellowship at Mount Hamilton.

Dr. H. D. Curtis, absent almost continuously from Mount Hamilton since August, 1917, at present head of the optical department in the Bureau of Standards, Washington, D. C., will return to his astronomical duties on Mount Hamilton about May 1st.

Professor William H. Wright, absent from Mount Hamilton since January, 1918, chiefly on indirect war service in the Students' Observatory, Berkeley, and during the last quarter of 1918 in the United States Government Artillery Service, Aberdeen, Maryland, is again in the Astronomical Department at Berkeley. It is expected that he will return to Mount Hamilton about July 1st.

GENERAL NOTES

The Interior of a Star[1]*; A Review.*—Professor A. S. Eddington of Cambridge, England, has derived some singularly important conclusions as the result of a theoretical study of the interiors of stars. Altho the problem of the conditions within a star appears very difficult, it is, nevertheless, theoretically simpler than the study of the interior of the Earth. The diffuse giant stars are very favorably adapted to this problem. On account of their extremely low densities they may be considered as large, intensely heated spheres of gas, acting in accordance with the laws of the kinetic theory of gases. Since the visible exteriors of these stars are vastly hotter than any terrestrial heat source, it must follow that near their centers the temperature must rise to some millions of degrees Centigrade. It is well to consider whether such a temperature, which is so far outside our experience, can be taken literally. In a mass of helium at 10,000° the ultimate particles move at the average rate of about 7.3 kilometers per second; at 1,000,000° the rate is 73 kilometers per second. Thus a hundred-fold increase in temperature means only a ten-fold increase of molecular speed. We never hesitate to accept the first temperature with its corresponding molecular speed, and there seems to be no reason why we should not accept the second with its corresponding molecular speed, since such speeds are not unknown in the laboratory. (It has been found, for instance, that alpha particles move with speeds approaching the speed of light.)

The existence of a high temperature in the interiors of stars should encourage investigation because it simplifies the problem. Under such conditions the radiant energy is not light in the ordinary sense; it becomes X-rays for which the absorption approaches more uniform laws. Further, at high temperatures the complex structures of the atoms are broken down into their constituent parts and thus the entire mass becomes homogeneous in composition.

Professor Eddington has calculated the temperature conditions within a typical star of mass 1.5 times that of the Sun, and density 0.002. At the center, where the temperature, pressure, and density are greatest, the temperature is 4,700,000°; the density is about one-ninth that of water and the pressure is 21,000,000 atmospheres. Half way from the center to the surface the temperature is

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[1] A. S. Eddington, The Interior of a Star, *Scientia*, Vol. XXIII, No. LXIX, 1, 1918; also *Astrophysical Journal*, November, 1918.

1,300,000°, four-fifths of the way it is 330,000°. Altho the decline in temperature as the surface is approached appears rapid, the temperature gradient is only 1.5° per kilometer—much less than that of the Earth's atmosphere. The effective temperature of this star is 6,500°; *i. e.* if the star were a black body at that temperature it would radiate as much heat as the actual star does. From Professor Eddington's theory it appears that for giant stars of equal masses the effective temperature is proportional to the sixth root of the density.

There is a close correspondence between spectral type and effective temperature. The class M stars have an effective temperature of about 3,000°. Stars with spectra like the Sun's (class G) have an effective temperature of 6,000°; for the white Sirian stars (class A) it is 11,000°; and for the hottest of all, the helium stars (class B), it may be estimated at 15,000°.

By taking account of the probable nature of the deviations from the laws of a perfect gas, Professor Eddington has extended his studies to the denser stars. The results of course are much more uncertain. As the star passes thru the various steps of the ascending temperature series of stellar evolution (the giant stage) the effective temperature rises as the surface contracts. It is of interest to inquire whether the net result is a loss or gain in brightness, since the decreasing area and the increasing radiation per unit area tend in opposite directions. The temperature-density law, stated in a previous paragraph, supplies the answer. The two tendencies just balance each other and therefore the total luminosity remains constant. The star reaches its greatest effective temperature when its density is 0.2 to 0.4. After that it enters the descending temperature series (dwarf stage), and from then on there is a rapid decline of temperature as the density slowly increases. The luminosity also falls off rapidly, since both surface and surface brightness are decreasing. The maximum temperature and luminosity are proportional to the star's mass. Differences in absolute magnitude of stars in a similar stage of stellar evolution may therefore be attributed to differences in mass. It may be noted, however, that the range of observed mass differences is very small. A ratio of 1:3 would include nearly five-sixths of all the known star masses. A body with mass less than one-seventh the Sun's mass would never attain 3,000°, which is the lowest temperature admissible if it is to shine as a star. As yet no star with such a small mass has been found. The Sun may have reached a temperature of 9,000°, a little lower than that of *Sirius* at present; it is now 6,000°. In order to attain the helium stage (class B), which is the hottest of all, a star's mass must be at least 2.5 times that of the Sun. It is significant that observations of class B stars have shown them to be on the average three times as massive as the average star.

Heretofore astrophysicists have not considered radiation pressure as a factor in theories of stellar equilibrium and evolution. Professor Eddington shows that for stars of sufficient mass, the pressure of internal radiation may nearly neutralize the force of gravitation. He has computed the ratio of radiation-pressure to gravitation for stars of various masses. The values are given in the following table, where M is the mass in terms of the Sun and R is the ratio of radiation-pressure to gravitation:

M	R
0.5	0.036
1.0	.106
1.5	.174
3.0	.320
4.5	.409

There is a significance in the rapid increase of radiation-pressure with increasing mass, which may appear clearer from another standpoint. Taking a series of globes of perfect gas, the first being a mere bubble containing 10 grams, the second 10^2 grams, the third 10^3 grams, and so on, Professor Eddington calculated the ratio of radiation-pressure to gravitation for each of these "stars." For the first thirty-three spheres—those with masses from 10 to 10^{33} grams—radiation-pressure is less than one-tenth of gravitation. From the thirty-fifth sphere onward the ratio is more than eight-tenths (it is always less than unity). We see, therefore, that thruout the first group radiation-pressure is only of trivial importance; but that in the second group it must entirely change conditions, since it neutralizes the greater part of gravitation. The transition between the two conditions of the series is represented by the single sphere of mass 10^{34} grams. The interesting point about this mass of 10^{34} grams is that it represents quite closely the usual masses of stars, being, in fact, five times that of the Sun. The coincidence is striking. The material of the universe has been aggregated into stellar bodies which are remarkably uniform in mass. By a simple argument from the properties of matter, involving only constants determined in the laboratory, Professor Eddington has singled out a critical mass—one at which a vital change of condition takes place—and shows that this mass is very near the average stellar mass. A star would become unstable if its mass were much larger than this. The radiation-pressure would be so great that gravitation could not hold it together. A body with a mass much less than the critical mass could never attain incandescence. The range for stellar masses is therefore definitely limited and we are led to believe with Professor Eddington that "radiation-pressure is indeed the prime agent which has fashioned chaos into stars."

HUGO BENIOFF.

The Evolution of the Binary Systems[1]*; A Review.*—In the December *Monthly Notices* there appears a discussion on "The Evolution of Binary Systems," by J. H. Jeans. In it are discussed different hypotheses as to the evolutions of binary systems with special reference to their periods and eccentricities. The following hypotheses are considered:

(A)[2] The periods and dimensions of orbits of binary stars are at present undergoing changes of the same nature as those which in the past have brought them to their present state of development.

(B) "The periods and dimensions of orbits of binary stars are permanently fixed, and have retained approximately their present values thru the whole of the star's life."

(C) "The periods and dimensions of orbits of binary stars, altho now definitely fixed, have been determined as the result of interactions with other stars in some past epoch in which these interactions were not negligible."

Considering (A) the author points out the fact that at present the interactions of adjacent stars are entirely inadequate to produce appreciable changes in the periods and dimensions of binary stars. We know of no other external forces which might be effective. This leaves only internal forces to be considered. It is shown from the principle of the constancy of the moment of momentum of an undisturbed system that great changes could not occur in the dimensions of the orbits except thru the agency of external forces. In particular any increase in the moment of momentum due to orbital revolution must be at the expense of the moment of momentum due to axial rotation. Now such an increase in the moment of momentum due to orbital revolution must occur if the semi-major axis increases. It is readily shown that the axial rotation does not provide a sufficiently large store of moment of momentum to account for any great increase in the semi-major axis. These considerations render (A) untenable.

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[1] J. H. Jeans, The Evolution of the Binary Systems, *Mon. Not. R. A. S.* **79**, 100, 1918.

[2] This hypothesis is not stated explicitly by the author, but it is discussed.

With regard to (B) the author considers that Russell's investigation[3], "On the Origin of Binary Stars," provides a strong proof that binary and triple systems have originated by fission. Such systems of long period as *α Centauri*, however, if formed by fission must originally have had a much smaller orbit, because if the object had remained unchanged, it would require that the density of the body at fission had been so low as to make fission practically impossible. This eliminates hypothesis (B).

There only remains (C). Encounters with other stars are considered as a means of altering the elements of a binary orbit. The author shows that after a sufficient number of encounters with other stars the eccentricity will become about 0.64 regardless of what it was originally. He states that the mean eccentricity of known binary orbits is slightly less than 0.6, so that the agreement with theory is satisfactory when we consider that we should not expect that all of the stars had reached the equilibrium conditions produced by a very large number of encounters. He states that the period will depend on the mass of the binary and on the velocity of translation of its center of gravity thru space. For a star ten times the mass of our Sun and whose velocity of translation thru space is 8 kms. a second, the period would be eighty years. This is of the right order of magnitude.

As the stellar system is now constituted encounters are too rare to have any such effects in conceivable time. If, however, the stellar system was once a nebula from which the stars have condensed, it must have been much smaller than at present to account for the large masses of the Sun and stars.

Such being the case, encounters must have been much more frequent and the orbits of binary stars thus brought to their present state. Since then the stellar system must have undergone an expansion and may even now be expanding. The observed excess radial velocities of stars of the different spectral types are considered by the author to be possibly a result of this expansion. If the B-type stars were formed after the stellar system had expanded somewhat, they must have suffered less from encounters than the older stars. The short periods of those among them that are binaries, together with the fact that they show a tendency to group themselves in clusters of stars having a common motion lends support to this view.

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[3] H. N. Russell, On the Origin of Binary Stars, *Ap. Jour.*, **31**, 185, 1910.

C. D. SHANE.

Comet 1918 a (*Reid*).—A brief note in the December, 1918, number of these PUBLICATIONS called attention to the discovery of an unexpected comet on June 11, 1918, by Mr. William Reid of South Africa. At that time, and until very recently, the original cable announcement of the discovery was the only information which had been received. The elapsing of many months without supplementary knowledge was due exclusively, it seems, to the difficulties of communication arising from war conditions. A letter written by Mr. Reid and addressed to the chairman of the Comet Medal Committee of this Society travelled only as far as London, whence it was returned to the sender.

Recent information from the Cape of Good Hope Observatory and from Mr. Reid establishes that the comet was kept under observation for nearly two months and that it followed closely the orbit computed by Mr. H. E. Wood of the Union of South Africa Observatory. Several satisfactory photographs were obtained at the Cape Observatory.

The comet passed perihelion about June 5, 1918, at a distance approximately 1.08 times the Earth's mean distance from the Sun, and its orbit plane made an angle of about 70° with the plane of the ecliptic.

Promptly following the receipt of the above information the Donohoe Comet Medal of the Astronomical Society of the Pacific was awarded to Mr. Reid, as announced on another page of this number of the PUBLICATIONS.

Mr. Reid is an enthusiastic comet seeker. He has found several comets, but the comet of last June is the only one of which he has been the earliest discoverer. His observatory is equipped with a 4-inch Alvan Clark refractor and a 6-inch Cooke refractor.

W. W. CAMPBELL.

A Tribute to Professor E. C. Pickering.—At the seventh annual meeting of the American Association of Variable Star Observers, which was held at the Harvard College Observatory, Cambridge, Mass., on November 23, 1918, a solid gold paper-knife set with alexandrite and a star-sapphire was presented to Professor E. C. Pickering, by the Association. The reverse of the inscription reads: "This token of appreciation is tendered to him who has done so much to promote the study of variable stars; guiding the amateur with untiring helpfulness along paths of understanding into fields of usefulness and pleasure."

It is fitting that the last public tribute paid to Professor Pickering was in recognition of his encouragement of the work of others.

Correction to a Note on the Size of the Hydrogen Envelop Star—In lines 3 and 5 of page 64 of the February, 1919, number of these PUBLICATIONS, the value of the parallax of the star should read $0''.0006$ instead of $0''.006$, as may be seen from the simple application in the note.

W. CARL RUFUS.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD MARCH 29, 1919, AT 2.00 P. M., IN THE OFFICE OF PRESIDENT BEVERLY L. HODGHEAD, IN THE HOLBROOK BUILDING, SAN FRANCISCO, CALIF.

There were present President BEVERLY L. HODGHEAD and Directors C. S. CUSHING, A. H. MARKWART, J. COSTA, MRS. ISAAC ROBERTS, R. G. AITKEN, J. C. CEBRIAN, BERNARD BENFIELD and D. S. RICHARDSON.

The minutes of the previous meeting of the Board, as printed in the February issue of the PUBLICATIONS, were approved without reading.

The following new members were elected:

To Life Membership:

Dr. S. L. BOOTHROYD, of the University of Washington.

To Active Membership:

Lt. JOHN F. DRYDEN, of Newark, N. J.
Mr. W. F. BUNYAN, of Heroult, California.
Mr. HARRY P. GATRELL, of Vancouver, B. C.
Mr. HARRY N. WRIGHT, of Whittier, California.
Mr. N. J. GOMPERTS, of Gotenborg, Sweden.
Mr. Naozo Ishinohe, of Tokyo, Japan.

To Student Membership:

Miss EDITH E. CUMMINGS, of Mt. Hamilton, California.

The Secretary read the reports of Mrs. Isaac Roberts and Mr. Bernard Benfield, constituting the committee which represented the Astronomical Society of the Pacific at the meeting of the Affiliation Committee of the Pacific Division of the A. A. A. S. which was held in San Francisco on February 20th. These reports, which detailed the steps being taken for the meeting of the Pacific Division at Pasadena in June next, were approved and ordered placed on file.

Director Aitken, who has had charge of the work of getting out the volume of Stahl Lectures, reported gratifying progress and exhibited to the Board a number of sample sheets and illustrations. He stated that the book will be ready for distribution in about four weeks and gave a verbal statement of expenses so far incurred, which indicated that the fund so generously provided by Mr. Stahl for this purpose will fully cover the cost of the work.

Communications were read from Directors George E. Hale and William H. Crocker, tendering their resignations as members of the Board of Directors. Same were accepted.

The Board then proceeded to fill the two vacancies created by these resignations, by unanimously electing Dr. W. W. Campbell and Mr. J. D. Galloway as members of the Board.

Dr. Campbell and Mr. Galloway, who were present, assumed their duties at once and took seats in the Board.

The adoption of the following resolution was moved by Director Cushing. It was seconded by Director Galloway and, after full discussion, was put to a vote and unanimously adopted by vote of the eleven Directors of the Society hereinbefore named:

"*Whereas*, heretofore Miss Catherine Wolfe Bruce, of New York, created with this Society a trust fund known as 'Bruce Medal Fund,' to be administered subject to certain statutes adopted for the bestowal thereof, which trust fund was heretofore duly accepted by this Society to be administered pursuant to said statutes; and

Whereas, in and by the same statutes, Article V thereof, it is provided that nominations by the director of each of the following observatories, namely:

The Harvard College Observatory,
The Lick Observatory,
The Yerkes Observatory,
The Observatory of Berlin,
The Observatory of Greenwich,
The Observatory of Paris,

are to be obtained prior to the award of such medal; and

Whereas, in and by said statutes, Article VII thereof, it is further provided that: 'It is competent for the eleven Directors of the Astronomical Society of the Pacific, by a unanimous vote, and not otherwise, to substitute for any one of the observatories named in Article V some other observatory'; and

Whereas, it is deemed desirable to make such a substitution and to substitute in said Article V the Argentine National Observatory at Cordoba, Argentine Republic, S. A., for *The Observatory of Berlin;* and

Whereas, the entire board of directors, to-wit, eleven members thereof, of this Society, is now assembled,

Now Therefore Be It Resolved by the unanimous vote of said Board of Directors, being the vote of the following directors, to-wit: Beverly L. Hodghead, W. W. Campbell, Charles S. Cushing, A. H. Markwart, J. Costa, Mrs. Isaac Roberts, Robert G. Aitken, J. C. Cebrian, Bernard Benfield, John D. Galloway and D. S. Richardson, that the *Argentine National Observatory at Cordoba, Argentine Republic, S. A.*, be and it is hereby substituted for the Observatory of Berlin where the same appears in Article V of said statutes for the bestowal of the Bruce Medal."

Adjourned.

D. S. Richardson,
Secretary.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD ON MARCH 29, 1919, AT 8.00 P. M., AT THE KNIGHTS OF COLUMBUS HALL, SAN FRANCISCO, CALIF.

President Hodghead presided at the meeting, and, after a brief résumé of the recent activities of the Society, introduced Dr. W. W. Campbell, Director of the Lick Observatory, as the speaker of the evening. Dr. Campbell announced as his subject, "What Are the Spiral Nebulae?". His address, which was one of the series of Stahl Lectures, was illustrated by many lantern slides, and was enjoyed by a large gathering of members and friends of the Society.

Adjourned.

D. S. RICHARDSON,
Secretary.

OFFICERS OF THE SOCIETY.

BEVERLY L. HODGHEAD	*President*
R. G. AITKEN	*First Vice-President*
MRS. ISAAC ROBERTS	*Second Vice-President*
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Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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ON THE NAVIGATION OF AIRPLANES

By Henry Norris Russell

1. *Introductory.*

The present paper contains an account of investigations on the determination of the geographical positions of airplanes by means of sextant observations made during flight. These studies were made under the authority of the Division of Science and Research of the Bureau of Aircraft Production (in whose service the writer was at that time engaged as an engineer), and the present account is published by permission of Colonel Millikan, who was at that time in command of the Division. Most of the work was done at Langley Field, Hampton, Va., where every facility was afforded by the Commanding Officer, Major Howard, and those subordinate to him in authority. Observations in naval seaplanes were also secured through the courtesy of the Commanding Officer of the Naval Air Station at Norfolk. In the conduct of the observations, the writer received assistance of the greatest importance from Captain D. L. Webster (now Professor at the Massachusetts Institute of Technology), to whose skill in piloting a great part of the success of the investigation is due; from Mr. J. P. Ault, navigating officer of the non-magnetic vessel *Carnegie*, who was assigned to this work by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and brought to it exceptional skill and experience in navigation at sea; and from Professor R. W. Willson of Harvard, whose bubble telescope proved to afford the best solution of the problem. Valuable aid and cordial interest in the work were also shown by many pilots and other officers at Langley Field and the Naval Air Station, to all of whom the writer offers his hearty thanks.

There is no difficulty whatever in handling a sextant in an airplane. It is desirable, tho not necessary, to use a rather small and light sextant, since the cockpit in which the observer sits is small, and the wind due to the motion of the "ship" is strong. For most purposes it is better to remove the telescope altogether and observe with the naked eye, especially if the horizon is at all indistinct. If a telescope is used, it should be of low power and large field. Clearness of graduation and ease of reading of the arc are important, and a vernier that can be read with the naked eye is much better than one which requires a reading glass. It is often sufficient to read the arc alone, estimating tenths of a division on it in the ordinary fashion.

The continuous wind and the necessity of wearing gloves in winter, complicate the recording of observations. After some experiments, the writer settled upon the use of a small lap-board of heavy millboard, with the watch wired down at one corner, and a small, well-bound notebook held open upon it by two rubber bands. With a couple of pencils tied firmly to this board, the observer is no longer in danger of losing his records, and both sextant and notes may be held safely between his knees if the pilot enlivens the descent in an acrobatic fashion.

No difficulties of any account were met with in making observations at altitudes up to 16,000 feet, at speeds up to 105 miles per hour, or at the lowest temperatures which were encountered (about 20° Fahr.).

The principal difference between observations in the air and elsewhere consists in the greater variety of horizons which may be met with. Under favorable circumstances, the sea, or flat land, may afford an excellent natural horizon. At other times, the upper surface of clouds or of a layer of haze may serve as a horizon. Failing all these, some form of artificial horizon must be devised. The third of these alternatives is the most frequently encountered.

2. *Observations with Sea or Land Horizon.*

When the aircraft is above flat land or in sight of the sea and the air is clear enough, observations on the natural horizon can be made as easily as at sea, and with almost the same accuracy. Really level land, such as the coastal plain of Virginia, over which most of the observations were made, forms a better horizon than the sea, since it presents a greater contrast with the sky and can be seen from a greater altitude. The greatest height from which the sea horizon was observed was 10,600 feet; the land horizon, 12,400 feet—both during a short spell of exceptionally clear weather in August, 1918.

So long as the horizon can be seen at all, the accuracy of observation varies but little with the height of the airplane. This is illustrated by Table I, which includes all the results secured upon horizons of this type except those obtained during the first part of the observer's first flight.

TABLE I

Limits of Altitude (Feet)	Average Error of One Observation	Number of Observations
40 to 250	±2′.3	34
250 to 1,000	±2 .5	40
1,000 to 4,000	±3 .1	21
4,000 to 10,000	±3 .8	19
10,000 to 12,400	±3 .9	15
All Altitudes	±2 .9	129

A single observation of this accuracy suffices to fix the Sumner line with all the precision necessary in aerial navigation.

Among the usual corrections to the observed altitudes, the dip of the horizon may acquire remarkably large values. To test the proportionality of this to the square root of the height, the observations were reduced with the dip as the unknown quantity, and group means formed as given in Table II.

TABLE II.—Dip of Horizon

Mean Square Root of Height in Feet	Mean Observed Dip Minutes of Arc	Number of Observations
5	5	7
8	9	21
14	15	6
18	19	13
23	22	17
26	26	6
30	30	5
41	42	6
50	51	6
59	60	5
71	72	4
80	82	8
89	89	7
101	103	8
108	105	7

It is evident that the assumption that the dip in minutes is equal to the square root of the height in feet is substantially accurate at all heights. The ratio of the former to the latter, as determined from a least square solution from the tabular data, is 1.007 ± 0.004. As the altimeters used for reading the altitudes were not specially calibrated, great weight cannot be laid on the absolute value of this coefficient; but as the observations were made from three different airplanes (and hence with different altimeters) during seven flights, including one at night, the mean value should be trustworthy. It indicates that the effect of refraction in diminishing the dip of the horizon is of about the same proportional amount at these great altitudes as at small heights. In deriving the tabular values, the refraction was applied with its full value for sea-level, but, as the observed altitudes were considerable, correction of the refraction to correspond with the lower density of the air at high altitudes would not affect the tabular data sensibly.

3. Observations on Cloud and Haze Horizons.

Under average conditions, the land or sea horizon is lost at an altitude of one or two thousand feet, since, even in "clear" weather, the lower air is usually full of haze. More often than not, however, this haze has a sharp upper boundary, at a definite level; and, when the ship has climbed well above it, it presents a definite "false horizon," which is always dark and usually sharp in the direction opposite to the Sun, but whitish and more diffuse under the Sun. Such a layer of haze may persist for weeks with variations in the height of its upper surface from day to day.

Observations upon such false horizons may be used provided that the height of the top of the haze above sea level is known, so that the dip may be computed. When, as often happens, the top of the haze coincides with the summits of low-lying scattered clouds, its altitude may be accurately determined when passing thru it on the ascent and descent. In the absence of clouds, the observer's estimate may be a few hundred feet in error.

A summary of the results obtained upon such horizons is contained in Table III. The first column gives the date; the second, the number of observations on the false horizon; the third, the average error, regardless of sign, of one observed altitude, corrected for the dip corresponding to the observer's height above the haze; the fourth, the error of the mean of all the observations, taking account of signs; and the fifth, the height of the top of the haze as estimated on the ascent and descent. The last three columns will be explained later.

On August 22nd, two horizons were simultaneously visible, one above the other; but only the observations on the lower one appear to be of value. With this exception, the observations in August and September are uniformly good enough to be useful.

The outstanding errors of the means may be explained by errors of a few hundred feet in estimating the height of the upper surface of the haze.

TABLE III.—OBSERVATIONS ON FALSE HORIZONS

Date	No. of Obs.	Average Error of one Obs.	Error of Mean	Observed Height of Haze (Feet)	Distance of Ridge (Miles)	Height of Ridge (Feet)	Average Residual Error
Aug. 16	5	±12′	+ 5′	6,600	....	.....	...
" 21	14	± 6	0	2,800	....	.....	...
" 23	26	± 6	+ 4	10,000	....	.....	...
" 23	5	±26	− 1	11,300	....	.....	...
" 24	12	± 4	+ 2	3,300	....	.....	...
Sept. 9	8	±11	−11	3,000	....	.....	...
Nov. 13	9	±22	−22	3,600	36	4,700	±8′
" 14	4	±26	−26	3,200	30	5,200	±4
" 25	7	±70	−70	3,200	31	7,000	±4
" 26	7	±69	−69	3,500	100	14,800	±2
" 29	19	± 7	− 7	4,000	....	.....	...
" 30	12	±18	+14	4,000	17.5	4,400	±5

On the contrary, the observations in November, when there was a persistent false horizon apparently similar to those seen in the summer, are quite valueless. This remarkable difference seems to indicate that the surface of the haze was in summer nearly uniform and level, while in late autumn it was irregular, so that the apparent boundary was not a true horizon but the top of a ridge of haze, rising above its general level. The dip of such a ridge below the theoretical horizon would vary linearly with the height of the observer, instead of being proportional to its square root; and, unlike a real horizon, it may be above the theoretical position and have a negative dip.

The observations of November 26th may be taken as an illustration. They are given individually in Table IV. The first column gives the observer's altitude; the second, the observed dip; the third, the dip computed for the haze surface at 3,500 feet which was passed thru and definitely located on both the ascent and descent; the fourth, the dip calculated from the empirical expression $0.0066\,(h-8200)$ where h is the observer's height in feet; and the last, the residual discordances between the observations and this formula.

The observed rate of change of dip, 6′.6 per thousand feet, corresponds to a ridge at the distance of 100 statute miles from the observer. In this distance, the Earth's surface curves away from the tangent by 6,600 feet; hence the top of the ridge, which lay on the theoretical horizon of the observer at 8,200 feet, must have been 14,800 feet above sea level. The assumption that the observed "horizon" was actually such a ridge, represents the observations with an average residual of only ±2′, which is all that could be wished.

When it is further noticed that the observed horizon was in all cases far above the computed position of the haze horizon, and above the theoretical horizon for the last observation, there can be no doubt that the suggested explanation is the true one.

TABLE IV.—OBSERVATIONS ON CLOUD RIDGE

Height in Feet	Observed Dip	Computed Dip for Haze at 3,500 Feet	Empirical Formula	Residuals
11,800	+22′	+90′	+24′	−2′
10,900	+22	+87	+18	+4
10,300	+13	+82	+14	−1
9,800	+ 7	+79	+10	−3
9,300	+ 4	+76	+ 7	−3
8,900	+ 1	+74	+ 3	−2
8,200	0	+69	0	0
5,800	−15	+48	−16	+1

On this occasion it was noted at the time of observation that the "horizon" was apparently above the level of the false horizon to the northward, and was probably a strip of cloud. But at several other times observations on apparently good haze horizons gave similar results, which could in all cases be satisfactorily explained on the assumption of a distant ridge of haze. The computed height and distance of this ridge, derived in the manner just illustrated, are given in the sixth and seventh columns of Table III, and the average outstanding residuals in the last column. The latter are satisfactorily small in all cases. Except on November 30th, the observed horizon was higher than the computed position of the haze horizon, the ridge of haze concealing what lay beyond it. On the latter date it was lower, indicating that the surface of the haze beyond the ridge was lower than in the vicinity of the observer. On November 29th the observations were all made while the airplane was at nearly the same height, so that the character of the haze horizon could not be investigated.

On two days observations were secured above an almost continuous sea of clouds. When the observer was well above the clouds, their upper surface presented a beautifully sharp and definite horizon. The results obtained are summarized in Table V.

On the first of the two dates the upper surface of the clouds must have been very nearly level, as is shown by the excellent accordance of the observations. But on the second the circumstances were very different. The height of the upper surface of the clouds was carefully determined on the ascent, descent, and when flying home close over them. Yet the observations all make the Sun's altitude much too small. In the table they have been combined into groups, for each of which is given the mean height of the observer, the mean error of the observed altitude, and the average difference of one observation from these means. The residuals average only ± 1′.3, showing that the observations were very good.

TABLE V.—OBSERVATIONS ON CLOUD HORIZON

Date 1918	No. of Obs.	Height of of Observer (Feet)	Height of Clouds (Feet)	Error of Mean Altitude	Average Deviation from Mean	Height of Clouds at Horizon (Feet)	Distance of Horizon (Miles)
Aug. 16	11	6,800 to 10,300	6,600	0′	±4′.5	....	..
Sept. 9	3	4,600	3,600	−30	±1.0	4,650	(3)
"	6	5,500	"	−22	±1.7	5,080	24
"	6	6,500	"	−18	±1.3	5,280	43
"	6	7,800	"	−15	±1.2	5,450	59
"	6	8,800	"	−12	±1.0	5,380	71
"	6	9,650	"	−12	±1.0	5,530	78
"	4	8,500	"	−14	±0.8	5,380	69
"	4	6,800	"	−13	±1.7	5,020	49
"	3	5,100	"	−16	±2.7	4,650	25

It is evident that the cloud horizon was considerably higher than its computed position, and the obvious explanation is that the upper surface of the clouds was actually higher in the region where the apparent horizon was situated than below the observer. As this region was out at sea, while the observer was well inland, the difference is not surprising. The last two columns of the table show the altitude of the cloud surface, which would explain the discordance for each group, and the corresponding distance of the horizon in statute miles. It is clear that the clouds rose steadily to seaward.

These observations do not cover a sufficient range of conditions to justify the drawing of general conclusions but it is evident that cloud or haze horizons, while sometimes good, are often unreliable and must be regarded with distrust.

It might be very inconvenient to have to descend to the level of the cloud or haze to find its height. This can be obviated by the use of a dip-measuring instrument, which permits a direct measurement of the amount by which the angular distance of two opposite parts of the horizon differs from 180°. Observations with such an instrument were made by Mr. Ault on four flights. The error of a single determination of the dip was of the order of $\pm 3'$ to $\pm 5'$, and might have been diminished if the instrument had been specially adapted to the demands of aerial observation. By measuring the dip in this way, the observed altitude is effectively referred to the mean position of two opposite points of the horizon and errors of the sort discussed above should be much diminished.

4. *Observations with Artificial Horizon.*

Weather conditions under which the natural horizon is visible from any considerable altitude are unfortunately rare, and it is necessary to devise some substitute. This problem, which is equivalent to that of determining the true vertical in a moving airplane, is of much importance in aviation, but is difficult, since any bodily acceleration of the aircraft affects the apparent direction of gravity for an observer moving with it. The resulting deflection of the vertical may reach 45° in an ordinary steeply banked turn, and in a well made loop it suffices to reverse the apparent direction of gravity—the pilot and observer being held in their seats by centrifugal force, while head downwards.

Even small deviations from uniform flying will produce serious deflections. If a deviation of $15'$ is adopted as the greatest permissible, it is easy to show that the speed of the airplane must never be permitted to change at a rate exceeding one mile per hour in ten seconds, nor must the radius of curvature of the path be less than ten miles (assuming a speed of sixty miles per hour). This evidently demands very careful piloting, but, as will be shown below, such a standard can be attained under favorable conditions.

It might be supposed that this restriction could be escaped by the use of gyroscopic apparatus. But to maintain the *vertical*, any apparatus whatever must ultimately be controlled by gravity as a directive force, and an instrument which could discriminate between the components of the apparent gravity relative to the airplane which arise from the Earth's attraction and from the reaction due to acceleration of the motion would furnish an experimental disproof of the Principle of Generalized Relativity. (Incidentally, it would also be unaffected by the acceleration due to the rotation of the Earth, and therefore would not indicate the direction of the vertical, as ordinarily defined, except at the equator or the poles.) All that can be hoped for from gyroscopic apparatus, therefore, is a lengthening of the free period of the swinging system, so that, when properly damped, it will not be sensibly affected by disturbing forces of short duration. To smooth out the irregularities in piloting, however, would require a free period of some minutes, and this would demand apparatus much too heavy and complicated for the present purpose. Damping against the rapid vibrations due to the engine is, of course, necessary, but can easily be provided.

The artificial horizon used in the present work was suggested by Major C. E. Mendenhall, and consisted of a pendulum mounted in gimbals so as to swing with equal freedom in any vertical plane, and bearing at its upper end a mirror adjustable so that its reflecting surface is horizontal when the pendulum swings freely. The lower end of the pendulum swings in a vessel of viscous liquid, which affords the necessary damping, while the whole instrument can, if desired, be supported on sponge rubber or other shock-absorbing material for further protection against vibration.

An experimental model was first constructed at the Science and Research Laboratory at Langley Field. The observations secured with this were so encouraging that two instruments of an improved type were constructed in the instrument shop of the Department of Terrestrial Magnetism, thru the courtesy of the Director, Dr. Bauer. These proved very satisfactory. The pendulum was about ten inches long, supported in ball-bearing gimbals, and carried a plane mirror of speculum metal, three inches in diameter. To protect the instrument from the strong winds due to the motion of the airplane, a cover with two glass plates inclined at about 40° to the horizon, and similar to those used on mercury horizons, was fitted over the top of the case.

The correct adjustment of the mirror is easily made by observing the double altitudes of some distant terrestrial object, and adjusting the levelling screws on which the mirror is mounted so that the same reading is obtained when the instrument is rotated about a vertical axis thru successive angles of 90°.

In observing with this instrument, double altitudes are measured just as in the case of a mercury horizon. During flight the image reflected by the mirror exhibits a small, rapid vibration due to the residual effects of the engine vibration and amounting usually to about ten minutes of arc. This makes it impracticable to set the two images tangent to one another in the usual fashion, but the center of the apparently fixed "direct" image of the Sun can be set opposite to that of the rapidly vibrating reflected image with an accuracy abundantly sufficient for practical purposes.

When the two images are watched for a few moments, however, it is seen that the reflected image, in addition to its rapid vibration, exhibits a much slower and irregular oscillation in a vertical direction, arising from the deflections of the apparent vertical due to accelerations in the motion of the airplane. The magnitude of these oscillations depends upon the steadiness of the piloting, and they are not uniform either in period or amplitude. The image will often be stationary for a considerable fraction of a minute, then shift in a few seconds to a new position, sometimes a degree or more from the first, and retain this for many seconds, then shift quickly to still another position, and so on indefinitely. Under the best conditions, these oscillations do not seriously interfere with observation, except that to obtain the desired accuracy the mean of several observations must be taken. With less skilful piloting or in bumpy air the oscillations become large and good results can not be secured. The observer, after a little experience, can easily recognize the periods of steadiest flying, and observe during these. He should be provided with a "gunner's belt" in place of the ordinary safety belt, so that he may have as great freedom of motion as possible, and means should be provided for shifting the artificial horizon rapidly from one side of the "ship" to the other.

The results obtained with instruments of this sort are summarized in Tables VI and VII—the former giving the observations with the preliminary model, and the latter those with the final instrument. A few wildly discordant observations have been rejected mainly because notes made at the time showed that the ship may not have been flying in a straight line. The exclusion of such observations is obviously legitimate. No observations have been rejected except for reasons which would have been apparent to the observer while in the air, immediately after making them.

After the errors of the individual observations were computed, they were combined into groups in the order in which they were made, and the error of the mean of each group calculated. The number of observations in a group depends on the accuracy of the individual settings, being greatest when these are poor. As observations can be made and recorded at the rate of two a minute, it is such a group, rather than the single setting, that should be regarded as the unit when estimating the practical value of the method. The first column in the tables gives the date; the second, the whole number of observations made with the artificial horizon; the third, the number rejected for cause, as explained above; the fourth, the average error, regardless of sign, of one of the remaining observations. The fifth column gives the number of groups into which the observations were combined; the sixth, the average number in a group (to the nearest unit); and the seventh, the average error, regardless of sign, for the mean result of one of these groups. At the foot of each table are given the mean values for all the observations made with each instrument, and for all the groups into which they were combined.

TABLE VI.—Observations With Preliminary Artificial Horizon

Date 1918	No. of Obs.	Rejected	Average Error of One Obs.	No. of Group	No. in a Group	Average Error of One Group
Aug. 21	2	..	±26′	1	2	±26′
" 28	18	..	±23	2	9	± 7
" 29	35	4	±26	3	10	±13
" 31	17	..	±23	2	9	±17
Sept. 7	28	..	±26	3	9	±11
" 9	6	..	±30	1	6	±21
All these	106	4	±25	12	8.5	±15
Sept. 23	160	..	....	16	10	±14

The observations of September 23rd, were made by Mr. Ault.

TABLE VII.—Observations With Final Artificial Horizon

Date 1918	No. of Obs.	Rejected	Average Error of One Obs.	No. of Groups	No. in a Group	Average Error of One Group
Nov. 12	8	1	±25′	1	7	± 7′
" 13	35	..	±39	5	7	±14
" 14a	7	1	±25	1	6	± 1
" 14b	7	..	±33	1	7	±14
" 14b	(15)	..	(±47)	(2)	(7)	(±43)
" 15	9	..	±42	1	9	±25
" 18	12	..	±30	2	6	±22
" 20	21	..	±25	3	7	±21
" 27a	9	..	±31	1	9	±10
" 27b	19	..	±38	3	6	±14
" 27b	21	..	±12	4	5	±44
" 29	24	..	±12	5	4	± 4
Dec. 5	15	1	±17	3	5	±10
All	202	3	±30	32	6	±14.3
Rejecting observations on November 14						
All	187	3	±29	30	6	±12.4

The observations on the second flight of November 14th are recorded on two lines. The first refers to measures on the Moon, which was at a high altitude and well observable, while the second deals with observations on the Sun, which was very low, so that the observer's position while using the sextant was extremely cramped and uncomfortable. These observations, in the mean, place the Sun 43′ too high. In the cramped position of the observer, it was much easier to see the reflected image near the top of the oscillations arising from the accelerations of the airplane than at the bottom, so that it is very probable that the image was observed mainly at the top of the oscillations, which would account for the systematic error. A similar error, but smaller and of opposite sign, occurs in the observations of November 20th, and can also be explained by a cramped position of the observer in the narrow cockpit. It is clear that observations should not be attempted unless the observer's position is reasonably free, and it appears justifiable to exclude the worst of these two series from the general mean, as has been done in the last line of the table.

Tables VI and VII illustrate above all the importance of good piloting in observations with artificial horizon. The new instrument, which was mechanically far superior to the old, gave no more accurate results for the reason that the instrumental errors of both were negligible in comparison with the effects of accelerations due to the piloting. All the largest errors in Table VII are explicable in this way. For example, on November 13th the pilot stated after the flight that the control wires to the elevator were somewhat slack, and that it was therefore impossible to hold the air-speed as uniform as usual. As the Sun was observed over the tail, this accounts directly for the large accidental errors. The most interesting case is the second flight of November 27th. This was made in a large naval seaplane. The twenty-one observations summarized in the lower of the two lines assigned to this flight were made while the controls were in the hands of Lieutenant Barrin, a naval aviator of great experience, while during the nineteen previous observations the ship was handled by an army pilot (Captain Webster) thoroly experienced with military airplanes, but who had never flown a seaplane of this type before and had neither landmarks nor compass to steer by. The same pilot, handling ships of types familiar to him, secured the very accurate results of November 29th and December 5th.

It is evident that to secure the best results the controls must be in excellent adjustment, and that the pilot should be not only experienced but familiar with his ship. The last three lines of Table VII show what can be done under these circumstances. For fifty-nine observations, the average error of a single setting is ±13′, and that of a group of five observations is only ±6′.4. It is of interest to note that these three flights were made in ships of different types—HSIL (seaplane), De Haviland 4 and JN6H. In deriving these figures, a correction to the observations was made for the effect of wind upon the exposed mirror of the artificial horizon, which made the Sun appear 16′ too high over the nose, and too low over the tail. The glass cover described above will eliminate this error.

5. *Observations with Bubble Sextant.*

The artificial horizon has several disadvantages: it is rather heavy, it requires to be shifted from side to side of the cockpit, and the observer's position is often inconvenient. These disadvantages are escaped by the use of an instrument devised by Professor R. W. Willson of Harvard University, who, upon learning of the present investigation, put it at the disposal of the observers, and came to Langley Field to help in the work.

Leaving a full description of this instrument to its inventor, it may be said here that it is an attachment to the telescope of an ordinary sextant, containing a level bubble moving freely on the under side of a spherical surface, and an unsilvered mirror inclined at 45° to the axis of the telescope, which reflects this bubble into the field of view. By an ingenious adaptation of the optical system, it results that a distant object which appears to be superposed on the center of the bubble will actually be on the true horizon, no matter at what point in the field of view both may appear to be.

In using the bubble telescope, it is attached to any ordinary sextant. An opaque screen is placed behind the horizon glass and the bubble is illuminated by the light of the sky thru the open end of the vertical bubble tube, or by a small electric lamp at night. The Sun is then "brought down" in the usual manner till it is visible along with the bubble in the field of view, and its image is then brought into the center of the bubble. The observations at first appear almost ludicrous—like trying to place an orange in the middle of a soap-bubble—but after a little practice readings may be made very easily and with surprising precision. The average error of a single setting, when the observer is standing or sitting on a fixed support, is about 1'.5, and this might be diminished by using a smaller bubble. The one in the instrument sent by Professor Willson was apparently 2°15' in diameter.

The manipulation of the instrument is very similar to that of an ordinary sextant. A rolling clamp, devised by Professor Willson, which made it possible to move the index arm smoothly and rapidly thru any desired angle, large or small, proved a great convenience. An additional index error is introduced by any imperfection of adjustment of the unsilvered mirror; but this can easily be determined by observing the sea horizon with the bubble, or by taking a series of altitudes of the Sun with the bubble and with an ordinary artificial horizon (removing the screen behind the horizon glass in the latter case).

When using this instrument in the air the engine vibration practically disappears, the observer's body and arms forming a very efficient shock absorber, and the viscosity of the liquid surrounding the bubble supplying the damping. The wind usually offers no serious inconvenience. Accelerations of the motion of the airplane produce oscillations of the bubble, similar in character to those of the image reflected in the artificial horizon, but much less conspicuous, as they might be mistaken for the shifts of the bubble due to unsteadiness of the observer's hand, when he becomes tired. On the whole, observation is decidedly easier with the bubble sextant than with the artificial horizon, and it is a great advantage to have but a single self-contained instrument to work with.

Observations were successfully made with this sextant during flight upon the Sun and Moon by day, and the Moon and stars by night. The results are summarized in Table VIII, which is constructed similarly to Tables VI and VII.

TABLE VIII.—OBSERVATIONS WITH BUBBLE SEXTANT

Date 1918	No. of Obs.	Rejected	Average Error of One Obs.	No. of Groups	Obs. in Group	Average Error of One Group
Dec. 18a	6	..	±45'	1	6	±14'
" 18b	81	4	±30	8	10	± 7
" 19	35	2	±13	8	4	± 5
" 20	11	3	±12	2	4	±12
" 21	10	..	(±50)	..	..	....
1919						
Jan. 9	19	3	± 7	4	4	± 2
" 10	49	6	±13	6	7	± 7
" 11	54	4	±23	7	7	±12
" 15	13	1	±16	3	4	± 9
All but Dec. 21						
	268	23	±21	39	6.3	±7.4

Here again the results indicate the dependence of accuracy upon piloting. The very large errors on December 21st were obtained in a short flight with a pilot who apparently did not fully realize the nature of the problem. These results are therefore omitted from the mean. The first flight of December 18th was above clouds and the pilot had no landmarks to steer by. After the flight of January 11th, the pilot, who had been steering by compass over the sea, stated that the compass did not respond to small changes in the course until a perceptible time after they had occurred. This explains the relatively large errors on this flight. The second flight of December 18th is more interesting. This was a long trip, lasting nearly an hour and a half, and the average error of an observation increased steadily with the time. The mean results for groups of nine or ten observations in successive order were: ±20′, ±30′, ±21′, ±30′, ±32′, ±30′, ±43′ and ±38′. Upon showing these results to the pilot, Lieutenant Cleary, he remarked at once that toward the end of the flight he was getting tired and not flying as evenly as at the beginning.

The remaining five flights, which represent what can be done under favorable conditions, give an average error, regardless of sign, of ±12′.8 for one of the 112 individual observations, and of ±6′.0 for the mean of a group consisting on the average of 4.9 observations. On account of the high accuracy of these observations, the occasional wild readings due to momentary acceleration were more readily detected, whence the greater number of rejected observations. Captain Webster was the pilot on four of these five flights.

The bubble sextant appears to leave very little to be desired as an instrument for aerial navigation. It is light, portable, reasonably rugged, easy to learn to handle and to manipulate under practically all conditions, and permits of observations of a precision much surpassing the limits set by the residual accelerations in even the most careful piloting. Perhaps the best example of its capacities is found in the last flight, when nine observations were made upon *Sirius*, the observer being in the front cockpit, and having to turn in his seat and observe behind the wings, while the ship was carrying two bombs and consequently not flying easily. Nevertheless, the average error for one setting was ±14′, and for the mean of the nine −2′.5.

6. *Reduction of the Observations.*

If the ship's position is to be determined by calculations made in the air, these must be simplified and abbreviated as much as possible. St. Hilaire's method should evidently be used—computing the altitude and azimuth of the Sun (or other body observed) at some assumed geographical position for the time of observation and drawing the Sumner line on a chart at right angles to the Sun's azimuth, and at a distance from the assumed position corresponding to the "intercept" or difference between the observed and computed altitudes.

Probably the quickest way of doing this is to select an assumed position in advance[1] (which may be anywhere within one or two hundred miles of the position of the airplane) and to compute an ephemeris of the Sun's altitude and azimuth for equal intervals of apparent solar time at this point. Corrections for refraction and parallax (and even for the index error of the sextant, if this is constant) can then be applied to the altitude, so that the ephemeris to be taken into the air gives directly the apparent altitude which should be observed, if the airplane was at the assumed position. If the observing watch is set to apparent solar time at this point, all that is needed to determine the computed altitude corresponding to any observation is a simple interpolation in this table, and the intercept is found by subtracting this from the observed altitude (corrected for semidiameter and dip, if the natural horizon is used). If a chart has been prepared on which lines have been drawn from the assumed position in the direction of the Sun's azimuth at half hour intervals, the Sumner line may then be drawn immediately, using a draftsman's triangle, graduated in nautical miles on one of the perpendicular edges.

An ephemeris of altitude for a whole day can be calculated in less than half an hour if Ball's Tables[2] are used, and occupies a space no larger than a postcard, while the Azimuth Tables of the Hydrographic Office[3] simplify this part of the work equally. If the assumed position is taken on an even degree of latitude, only a single interpolation for the Sun's declination is necessary.

By such precomputation the work to be done in the air is reduced to a minimum, and the danger of numerical errors is also minimized. Even in a transatlantic flight, this method could be applied by choosing in advance a series of standard positions, three hundred miles or so apart, along the track, and computing the altitude, etc., in advance for each, for such an interval of time as would safely cover the probable period when the ship would be near each position.

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[1] Compare G. W. Littlehales, *U. S. Naval Institute Proceedings*, March, 1918, pp. 567-584.

[2] Published by J. D. Potter, London, 1907.

[3] U. S. Hydrographic Office, Pub. No. 71, 1918.

But such extensive precomputations are not imperative. All the calculation can be done in the air without serious loss of time. One quick method is to use Aquino's Tables, which, by a suitable choice of the assumed position (not usually on an even degree of latitude or longitude) reduce the calculations to a very simple form. If this is done, the azimuth must be computed and the Sumner line drawn separately for each observation; but nevertheless the method is thoroly practicable, as was proved by Mr. Ault during a flight from Langley Field to Washington and return. The average time required to secure a set of ten observations with the artificial horizon was 4.5 minutes, for the computations 3 minutes, and for the plotting of the Sumner line 2 minutes, with the aid of a special protractor.

Still better, probably, would be the calculating machine recently designed by Professor Charles Lane Poor[1], which resembles a circular slide rule. With this the altitude corresponding to any assigned latitude, time and declination can be found in one minute of time to within one or two minutes of arc, and the azimuth in half a minute more. The assumed position can be taken on an even degree to simplify the plotting. The present model of this instrument is a little large for convenient use in a small airplane but a smaller one could easily be made.

7. *Practical Results.*

The best evidence of the degree of success that has been obtained in actual practice is to be found in the results of three days' work when sights on the Sun and Moon could be obtained almost at the same time, and a "fix" obtained by the intersection of two Sumner lines. On the first of these days, the natural horizon could be used, and single sights sufficed to give good locations. On the other two the bubble sextant was used and the Sumner lines determined from the means of a number of successive sights.

The results are given in Table IX. The first column gives particulars concerning the flight, the horizon employed, and the difference between the azimuths of the Sun and Moon. The next three columns give the errors of the geographical positions determined from each set of observations, in latitude (positive if too far north), departure (positive if too far east), and in actual distance between the true and observed position—all in nautical miles. The last two columns give the number of observations on which each result is based. Each determination is wholly independent of the others.

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[1] See his book, *Simplified Navigation* (Century Co., New York, 1918). This calculating machine is now on the market, but is expensive.

TABLE IX.—POSITIONS BY SUMNER'S METHOD

	Errors of Observed Position			Number of Observations	
General Data	Latitude	Departure	Total	Sun	Moon
Aug. 16, 1918; Over York River; Airplane, type JN4H; Natural Horizon; Angle of Sumner Lines, 126°.	+ 8	− 9	13	1	3
	− 2	− 5	5	1	1
	− 1	− 3	3	1	1
	+ 4	− 7	8	1	1
	+ 5	0	5	1	1
	− 3	− 6	7	1	2
	+ 2	− 6	6	2	1
	+ 1	− 9	9	1	1
	− 4	+ 2	4	1	1
	− 3	− 6	7	1	1
Jan. 10, 1919; Near Langley Field; Airplane, JN4H; Bubble Sextant; Angle 119°.	+ 2	+ 9	9	7	7
	+ 7	− 5	8	7	9
	+13	+ 2	13	9	9
Jan. 11, 1919; Off Cape Charles; Boat Seaplane, type H-16; Bubbel Sextant; Angle 141°.	+20	+14	24	8	8
	+18	+11	21	8	8

The average error of the actual location on the map for the ten determinations made with natural horizon is 6.7 nautical miles. The average time required to make the observations of one set was 2.3 minutes. For the five locations with the bubble sextant the average error is 15 miles, and the average time required for the observations, both of Sun and Moon, is 12 minutes. For the three sets on January 10th, when the piloting conditions were more favorable, the average error is only 10 miles.

So far as is known, these are the first occasions on which astronomical observations sufficient to determine completely the position of an airplane have been made during flight. They were not actually worked out in the air, as the object at that time was mainly to test the instrumental possibilities, especially as regards accuracy.

Mr. Ault, however, reports: "The first known instance of an airplane pilot being informed of his position by astronomical methods should be recorded here. During my flight from Langley Field to Washington, September 23, 1918, the visibility was very poor. The pilot, Lieutenant Charles Cleary, wished to verify his position, so slowed down and asked if the river below was the Potomac. I had just completed drawing in position line No. 5, which intersected our track at the Potomac river, so I was able to inform him that my observations placed us at the Potomac."

8. *Observations of the Sun's Azimuth.*

When only the Sun is observable but one Sumner line can be drawn. To find the observer's position on this line, Mr. Ault suggested that it might be possible to observe the Sun's magnetic azimuth, with a compass mounted in the airplane. Correcting for variation and deviation, the true azimuth is found, and this, under all ordinary circumstances, suffices to locate the point on the Sumner line at which the observation is made. From his report on preliminary investigations the following is abridged:

"A card graduated to half degrees from 0° to 360° was mounted on the preliminary artificial horizon mounting (so that its plane was horizontal) and a vertical pin mounted in the center of this card. The Sun's bearing was determined by noting the card reading of the shadow of the pin, reading simultaneously the magnetic heading of the airplane by the compass mounted nearby. The relation between the 0°-180° line of the card and the lubber line of the compass was determined when the airplane was "swung" on the ground to determine the deviations of the compass. On November 25, 1918, . . . nearly 120 observations of the Sun's azimuth were made on three different headings. The probable error of the mean of any ten observations was $\pm 0^\circ.6$, and the mean difference between the deviations determined on the ground and those determined in the air was $+0^\circ.1$. Only two of the twelve groups were in error over 1°." Similar observations made by Mr. Fleming, of the Department of Terrestrial Magnetism, gave the value $\pm 0^\circ.8$ for the average discordance of the mean of a set of ten readings from a smooth curve of the theoretical form for the deviation of the compass. Such a set could be obtained in from one to one and a half minutes of observation.

Further studies of this obviously very promising method were interrupted by the necessary return of Messrs. Ault and Fleming to other duties. It is highly desirable that they should be continued, for they give good reason to hope that determinations of position, accurate enough to be of much value to aviators, can be made by observing the altitude and azimuth of the Sun, when it alone is visible.

9. *Summary.*

1. Sextant observations may be easily made from airplanes. More than a thousand sights on Sun, Moon and stars have been made during the present investigation from airplanes and seaplanes of nine different types.

2. When the natural horizon is visible a single sight gives the altitude with an average error of 3′.

3. The relation that the dip of the horizon in minutes of arc is equal to the square root of the height in feet has been confirmed up to heights exceeding twelve thousand feet.

4. Horizons formed by clouds or haze, while sometimes valuable, are not reliable.

5. In the absence of a natural horizon, observations may be made with an artificial horizon or a bubble sextant. Both give good results, but the latter is lighter and much more convenient.

6. The chief error in such observations arises from the deviations of the apparent vertical, arising from irregularities of motion of the airplane. By very careful piloting, these have been reduced to an average of ±13′ for a single sight. With ordinary piloting they average twice as great and with careless piloting they would make observation useless.

7. It is therefore well to make several settings with the bubble sextant in rapid succession, and work up the mean of the group. The average error of the mean of groups of about six settings ranges from ±12′ for average piloting to ±6′ for very careful work. Such a group of observations can be obtained in from three to five minutes.

8. The necessary calculations may be much shortened either by doing most of the work before starting or by the use of rapid methods in the air. The whole time required for the plotting of a Sumner line from one sight or set of sights does not exceed five minutes, and may well be less.

9. When both the Sun and Moon were visible, determinations of position by Sumner's method showed an average error of location on the map amounting to 7 nautical miles when the natural horizon was available, and 15 miles with the bubble sextant (10 miles with the latter under good conditions). The whole time required for observation and calculation should be less than ten minutes in the first case and twenty minutes in the second.

10. Information regarding his position, determined with the sextant, has actually been furnished to a pilot during flight, and proved of use to him.

11. Methods of determining position from observations of the Sun alone, using its altitude and magnetic azimuth, have been provisionally tested with promising results.

It may fairly be concluded from the foregoing that the problem of finding the position of an airplane by astronomical means may be regarded as solved, within the limits set by the nature of the subject, and with sufficient accuracy for the practical purposes of aerial navigation. Over land, the pilot will doubtless be guided by landmarks, but on oversea flights and probably at times above clouds or fog, it is hoped that the investigations here recorded may prove of substantial usefulness.

Princeton University Observatory,
April 22, 1919.

SHALL WE REFORM THE CALENDAR?

BY W. W. CAMPBELL

In these post-war days when so many reformers, especially in America, are firmly resolved that the world shall be made a great deal better, all at once and without regard to the financial expense involved, patient men and women may not be in the temper to consider still another reform. However, the positive assurance that the subject in question does not touch the pocket-book—does not involve yet one more financial "drive"—may incline the reader to a deliberative state of mind. This reform concerns the *Calendar*. It is under discussion in many quarters, especially in France. The motive is exclusively the greater convenience of the general public which uses the calendar—identically the same motive which led to the adoption of the "Standard Time" system.

A brief history of the calendar will assist in making the problem clear.

The calendars up to the days of Julius Caesar were many, inconvenient and crude, because churches and states made ill-advised changes in the prevailing systems. These changes, for the most part, have been deciphered and recorded by historians, yet none but expert chronologists can interpret ancient time records of passing events in terms of the modern calendar. The foundations of the present system were laid by Julius Caesar, who called the astronomer Sosigenes from Alexandria to advise him. Julius ordained that the year should begin with January 1st (B. C. 46)—in the previous Roman system the year had begun in March; that there should be twelve months, the first, third, fifth, seventh, ninth and eleventh months to contain thirty-one days each; the fourth, sixth, eighth, tenth, and twelfth, thirty days each; and the second month, February, twenty-nine days in ordinary years and thirty days in each fourth or leap year. It is well known that he changed the name of the seventh month from Quintilis to July, in honor of himself.

The Julian Calendar would have worked fairly well for a few centuries. Now came Augustus Caesar, the successor of Julius, who must have a month of his own, with as many days therein as July contains. The eighth month (Sextilis) was accordingly changed to August, and one day was stolen from the already short month of February to make thirty-one days in his month. To prevent three successive months, July, August and September, from having thirty-one days each, the simple system of Julius as to thirty-one days in the odd months and thirty days in the even was changed by Augustus into the hodge-podge with which we struggle today.

The exact length of the year expressed in days, hours, minutes, and seconds was not known in the time of the Caesars. They had assumed it to be 365 days, 6 hours exactly, whereas it is 365 days, 5 hours, 48 minutes, 46 seconds approximately—and in fact the length of the year changes slowly. This discrepancy of more than eleven minutes caused the seasons to move forward slowly in the year. For example: at the time of the Council of Nice, 325 A. D., the Sun was in the vernal equinox, that is, it crossed from the south side to the north side of the equator on March 21st; whereas in the year 1582 this crossing had moved forward ten days to March 11th. By the latter date the length of the year had become known with considerable exactness, and Pope Gregory XIII, after consultation with the wise men of his day, especially the astronomer Clavius, decided to alter the calendar to make it keep step with the Sun. Thus, he decreed that the years which complete the centuries—1600, 1700, 1800, 1900, etc.,—should not be leap years unless divisible by 400; 1600, 2000, 2400, etc., are leap years, but 1700, 1800, 1900, 2100, etc., are not. This dropping of three leap years out of every 400 years allowed almost precisely, but not quite, for the discrepancy of eleven minutes, fourteen seconds, between the true and the assumed lengths of the year. Further to set matters right, according to his point of view, he decreed that ten days in the month of October, 1582, should be dropped; to be exact, that the day following October 4th should be called October 15th. This dropping of the ten days brought the date of the vernal equinox back to March 21st, where it had been in A. D. 325. The decrees of Gregory were promptly put into practice in the Roman Catholic world, but not so in the nations of the Protestants. It was not until 1700 that the Gregorian calendar began to rule in the Protestant states of Germany, and the change to the new calendar did not take effect in England until the year 1752.

The Greek Church refused to accept the Gregorian decree, and continued the Julian calendar in force. In Russia and some of the Balkan states holding the Greek Catholic faith, the years 1700, 1800, 1900, were leap years, and consequently the Russian calendar at the outbreak of the Great War was thirteen days behind the calendar prevailing in Roman Catholic and Protestant countries. It is understood that parts and possibly all of Russia, as well as the belated Balkan states, have now adopted the Gregorian calendar.

What is there to reform in the prevailing (Gregorian) calendar? It has several inconveniences, of which the most serious is the gross inequality in the lengths of the months. There is no simple rule expressing the length of the month; everyone must learn it as a purely arbitrary thing. Hundreds of millions of people must consider a score of times each year whether certain months have twenty-eight, twenty-nine, thirty, or thirty-one days. The abnormal shortness of February is especially inconvenient. There is reason for surprise on this account alone, that the system was not rescued long ago from the jumble of months which we owe chiefly to the vanity of Augustus Caesar. Again, the first day of the year, the first day of the month, a holiday, or any day of the year or month may fall in various years on any day of the week; and that is a greater inconvenience than we realize. It is a minor inconvenience of our calendar that always one month per year begins on Sunday; in many years there are two months and in some years three months beginning on Sunday.

How shall the faults of the Gregorian calendar be eliminated without introducing others equally serious? The subject is not an easy one. This arises from the immutable facts that there are not exactly a whole number of days in the year; that the centuries must be of two different lengths; that the years must be of two different lengths; that it is not possible to divide either the common or the leap year into an acceptable number of months equal in length; and that there is not an exact number of weeks in the month.

It has been seriously proposed by many reformers that there should be thirteen months in the year instead of twelve, because this division of the year would permit, conditionally, of a simple relationship between the week and the month. If there were thirteen months of twenty-eight days each—precisely four weeks each—364 days per annum would be accounted for. The proposers of this system suggest that the 365th day of the ordinary year be "New Year's Day," an extra day, not to be called by any day of the week, but to be known simply and solely as New Year's Day. The 366th day of leap year in this system would likewise be an extra day and be given a distinctive name, with no week-day name attaching to it, and it would fall either between the sixth and seventh months of the year, or at the close of December. This system has the advantage that all the months of the year would be of the same length, that all the months would begin on the same day of the week, and that any given day in each and every month, the seventeenth for example, would always fall on the same day of the week; but there is a fatal objection: the increase in the number of months in the year from twelve to thirteen would mean more work for banks and all sorts of accounting institutions and individuals. It is also certain that an unfortunate superstition which dwells with many weak-minded people would cause them to shy at the number "thirteen" as applied to a month.

From the many and varied proposals which retain the year of twelve months, but principally from M. Armelin's calendar—these proposals discussed chiefly under the auspices of the *Société Astronomique de France* in 1887, and recently in the *Paris Académie des Sciences*—I have selected the features which seem best to me, as in the following paragraphs.

1. The year of twelve months is divided into four quarters of three months each, and the arrangements for the first quarter repeat themselves precisely in each of the other quarters. The first month of each quarter has thirty days, the second month thirty days, and the third month thirty-one days. This accounts for ninety-one days in each quarter, or 364 days in all.

2. The remaining day in ordinary years is "New Year's Day." It is given no other descriptive title. It does not belong to any week or any month. It begins the year. January 1st is the day following New Year's Day.

3. The 366th day of leap year is likewise an extra day, bearing an appropriate descriptive name, perhaps "Leap Day," but no week-day name, nor is it a part of any month. It is the day following December 31st, and the day preceding New Year's Day. It is assumed to be a holiday—it comes only one year in four. It could follow June 31st, if preferred.

4. January 1st falls on Monday. From this it results that the first month in each quarter—January, April, July, October—begins on Monday in each and every year; that the second month in each quarter—February, May, August, November—begins always on Wednesday; and that the third month in each quarter—March,

June, September, December—begins always on Friday. The first day of the month never falls on Sunday; the fifteenth day of the month never falls on Sunday; the thirtieth day of the month never falls on Sunday; the last day of each quarter—the thirty-first of March, June, September, December—always falls on Sunday. The thirty-day months always have four Sundays each; and the thirty-one-day months always have five Sundays each. The number of "week-days" in the month is twenty-six for each and all of the twelve months.

The advantages of this simple system must be evident. The months are as nearly equal as they can be made, and in working days they are absolutely equal. Any given day of any month always falls on the same day of the week. A mind of modest ability will learn in a few minutes the week-day with which each month invariably begins, and will be able to compute quickly the day of the week upon which any day of any month falls. Each stated holiday falls upon its invariable day of the week. Thanksgiving Day falls always on November 30th.

The present proposal is completely outlined in the following brief table, which will serve for *all years alike*. It is a perpetual calendar; it needs to be printed but once. [To be exact, the 97 leap years in 400 years do not keep the seasons *precisely* in harmony with the years. It will be necessary to omit one additional leap day every 3,323 years. Starting with A. D. 325 as correct, the leap day should be dropped about the year A. D. 3048. Our successors will probably decree that either 3000 or 4000 shall be a common year.]

New Year's Day			
First Quarter	January	February	March
Second Quarter	April	May	June
Third Quarter	July	August	September
Fourth Quarter	October	November	December
Leap Day			
Monday	1 8 15 22 29	6 13 20 27	4 11 18 25
Tuesday	2 9 16 23 30	7 14 21 28	5 12 19 26
Wednesday	3 10 17 24	1 8 15 22 29	6 13 20 27
Thursday	4 11 18 25	2 9 16 23 30	7 14 21 28
Friday	5 12 19 26	3 10 17 24	1 8 15 22 29
Saturday	6 13 20 27	4 11 18 25	2 9 16 23 30
Sunday	7 14 21 28	5 12 19 26	3 10 17 24 31

New Year's Day	New Year's Day
Washington's Birthday	February 22, Wednesday
May Day	May 1, Wednesday
Decoration Day	May 30, Thursday
Independence Day	July 4, Thursday
Labor Day	September 4, Monday
[Admission Day (California)	September 9, Saturday]
Christmas Day	December 25, Monday
Leap Day	Leap Day

The transition to this or a closely related system should be made at the beginning of the particular year which will not break the continuity of the week in order to have January 1st fall on Monday. In the Gregorian system January 1, 1923, falls on Monday. In the proposed new system that particular interval of twenty-four hours would be called New Year's Day (of 1923) and the following day would be Monday, January 1, 1923. The next opportunity to introduce the system would come in 1934.

I think it may safely be said that the accounting operations of the world will not be increased at any point, but on the contrary, will be simplified at many points thru the adoption of this calendar. Some readers will undoubtedly urge that the break in the continuity of the weeks at the end of each year will be an inconvenience, and there is some truth in this. For example: from Saturday to Saturday of successive weeks will be seven days, as at present, except that the first Saturday of January will be eight days from the last Saturday of December in common years, and nine days in leap years. However, the world would soon accustom itself to this fact, and certainly the difficulty would be not nearly so serious as that of carrying counts of days from one month to another in the present system. It has been suggested that church organizations may object to the proposed reform on the ground that from Sunday, December 31st, to Sunday, January 7th, will be more than seven days; but we should remember that the Bible says: "Six days shalt thou *labor*, etc.," and the proposed reform is in full harmony with that law, as the "seventh day" is always Sunday. New Year's Day, forming the extra day in the "long week," is a holiday when no man worketh, and Leap Day, also in the long week, one year in four, would undoubtedly be decreed a holiday.

Deslandres, of the Paris Academy, proposes that the extra (365th) day of each year shall be called, not New Year's Day, but "Peace Day," and be placed between June and July. This is objectionable, at least from the American point of view, because it would add another holiday to the already long list, for in that case January 1st would undoubtedly be a holiday also, as in the present system. There is the further objection that the break in the run of the weeks would occur in the middle of the year, and again, in leap year, at the end of the year.

Bigourdan, also of the Paris Academy, proposed a calendar which does not break the continuity of the weeks. It is an improvement over the Gregorian calendar in that the year is divided into four (unequal) quarters of three months each, thirty-one days in the first month of each quarter, thirty days in the second month of each quarter, and thirty days in the third months of the first three quarters, but thirty-one days in December, with the extra day of leap year added to November, making that a month of thirty-one days every fourth year. In leap years four months in succession will have thirty-one days. Bigourdan's system has the advantage of making the months a little more equal than they are at present, and of simplifying slightly the run of the days thru the year, but the first day of the months, a given day of any month, and the holidays, fall on different days in successive years, as in the Gregorian calendar. His calendar is not perpetual and would have to be reconstructed and reprinted for every year.

No man and no single organization can foresee all the consequences which would result from changes in the calendar. Comments and criticisms are desirable. There are always people who will object to any change. The slight reforms introduced in the calendar by Pope Gregory met with violent opposition, yet Gregory was right, and the world is his debtor.

The proposal that the day should be divided into twenty-four hours numbered consecutively from one to twenty-four, instead of two series, as at present, numbered from one to twelve, could well be considered simultaneously. This reform has been in successful operation in Italy and in the railroad systems of other countries for many years. Its use in railroad time tables leaves the passenger in no doubt whatever as to whether the departure of trains occurs in the forenoon or the afternoon, and mistakes are similarly avoided in all departments of life.

The substitution of a rational series of names for the months could likewise be considered with advantage. The objections to the present system will be apparent to everyone who makes himself familiar with the origins of the names of the months. These origins are briefly as follows:

January,	from Janus, a Roman god, protector of doors and gateways, patron of the beginning and ending of all undertakings.
February,	from Februarius, the Roman month of purification and expiation.
March,	from Martius, the Roman god of war.
April,	from Aprilis, regarded by the Romans as the month when the Earth opens to produce new fruits.
May,	from the Latin Maius, third month of the early Roman year, named from the Greek Maia, eldest of the Pleiades, one of the wives of Zeus.
June,	from the Roman month Junius, named in honor of the Junius family.
July,	from Julius Caesar.
August,	from Augustus Caesar.
September,	meaning seventh, but it is the ninth month.
October,	meaning eighth, but is is the tenth month.
November,	meaning ninth, but it is the eleventh month.
December,	meaning tenth, but it is the twelfth month.

The utilization of ancient deities, of quite ordinary mythological characters, of families, of Roman emperors, and of numerical designations wrongly applied is not the sign of poverty of sources, but of a lack of system.

It has been suggested by Flammarion and others that the twelve months could well bear names expressing the higher ideal qualities of the human race, or of conditions to which we attach importance, such as truth, justice, goodness, wisdom, beauty, courage, liberty, equality, fraternity, independence, peace, etc. It would also be possible to base the names of the months upon the Latin words for the numbers one to twelve. This numerical plan, however, would be obliged to avoid a system with which the present names September, October, November, December would be uniform, as it would not do to move the four names forward to their proper positions with the seventh, eighth, ninth, and tenth months, in view of the confusion which would unavoidably be introduced.

It is clearly the wisest policy to introduce at one and the same instant, or as nearly as practicable at the same instant, all those reforms in the fundamental time systems whose adoption within the next half century can be foreseen.

The greatest difficulty confronting calendar reform will probably be found in the conservatism of national governments: parliaments and congresses will doubtless hesitate to enact the necessary legislation. There is also much merit in the point of view that "reformers" should incline toward conservatism in all matters affecting the daily life of the people, under present unsettled world conditions.

THE STELLAR SYSTEM Σ 3050 = ANDROMEDAE 37

(Burnham's *G. C.*, No. **12675**)

BY ERIC DOOLITTLE

The following investigation was undertaken in consequence of the interesting note by Dr. J. S. Plaskett in *A. S. P.*, No. 179. The velocity in the line of sight of each of the components was measured on five nights by him, with the new Brashear 72-inch reflector; it was found that the system is approaching us, but that the components are moving with slightly different velocities: the velocity of *A* in the line of sight is 4.6 miles a second, while that of *B* is but 2.6 miles a second. Dr. Plaskett regards it as so probable as to be almost a certainty that the two stars are physically connected.

As will be noticed from the tabulation below, the system has been many times measured with the micrometer. The number of measures total no less than 206 nights. The pair is a very easy one, the two components being of equal magnitude (6.58 according to Dr. Plaskett), and they are widely separated at all times; the errors of measurement should therefore be small. It was hoped that a careful investigation of this material would give definite evidence of the binary character of the pair.

The individual observations are as follows:

Date	θ_0	ρ_0	$\theta_0-\theta_c$	$\rho_0-\rho_c$	Observer	Nights
1821.92	188°.4	5″.26	−0°.6	+0″.93	Sh	2n
1830.04	189 .7	4 .37	−0 .9	−0 .15	Sh	1n
1830.73	189 .0	4 .07	+1 .4	−0 .03	Dawes	2n
1832.65	191 .0	3 .78	−0 .1	−0 .26	Σ	3n
1837.03	191 .7	4 .14	−0 .3	+0 .20	Dawes	2n
1843.81	193 .0	3 .65	−0 .5	+0 .14	Dawes	1n
1848.10	194 .9	3 .82	+0 .4	+0 .16	Maedl.	8n
1849.31	194 .5	3 .56	−0 .3	−0 .07	Dawes	2n
1855.49	196 .4	3 .55	−0 .1	+0 .07	Δ	7n
1855.98	196 .6	3 .50	±0 .0	+0 .03	Morton	3n
1857.51	196 .4	3 .44	−0 .6	+0 .01	Secchi	3n
1862.20	198 .2	3 .34	+1 .2	+0 .02	Maedl.	8n
1864.99	199 .6	3 .17	+0 .4	−0 .08	Δ	11n
1868.56	200 .7	3 .16	+0 .3	±0 .00	Duner	3n
1871.41	*201 .3	3 .00	±0 .0	−0 .10	Δ	6n
1875.70	203 .0	3 .06	+0 .1	+0 .06	Duner	3n
1876.06	203 .6	3 .09	+0 .6	+0 .09	Seab.	1n
1876.85	202 .2	3 .08	−1 ,1	+0 .09	Doberck	3n
1880.11	204 .9	3 .05	+0 .4	+0 .14	Jed.	3n
1883.77	206 .3	3 .02	+0 .3	+0 .18	En.	6n
1885.91	206 .0	2. 61	−0 .9	−0 .17	de Ball	2n
1886.81	207 .3	2 .87	±0 .0	+0 .11	H Σ	2n
1887.92	206 .8	2 .77	−1 .0	+0 .01	Hall	2n
1889.92	208 .6	3 .08	−0 .1	+0 .36	Maw	3n

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*Lewis has here 202°.3

Date	θ_0	ρ_0	$\theta_0-\theta_c$	$\rho_0-\rho_c$	Observer	Nights
1892.95	210 .0	2 .60	−0 .1	−0 .04	Jones	2*n*
1893.83	211 .1	2 .73	+0 .6	+0 .11	Glase.	4*n*
1894.13	210 .4	2 .86	−0 .3	+0 .24	Knorre	3*n*
**1894.30	210 .5	2 .66	−0 .2	+0 .04	Comst.	4*n*
1894.66	210 .6	2 .64	−0 .3	+0. 03	Collins	4*n*
1894.72	212 .2	2 .86	+1 .3	+0 .15	Niesten	2*n*
1897.02	213 .9	2 .70	+1 .8	+0 .14	Seabr.	2*n*
1897.21	212 .2	2 .57	±0 .0	+0 .01	Bowyer	5*n*
1897.92	212 .5	2 .67	−0 .1	+0 .13	Maw	3*n*
1898.84	214 .1	2 .40	+1 .1	−0 .12	Bryant	1*n*
1898.91	212 .4	2 .55	−0 .7	+0 .05	Aitken	2*n*
1899.83	214 .3	2 .40	+0 .8	−0 .10	Lewis	1*n*
1900.83	214 .3	2 .45	+0 .2	−0 .03	Doberck	2*n*
1901.10	214 .2	2 .47	±0 .0	−0 .01	Bowyer	4*n*
1902.59	213 .2	2 .32	−1 .8	−0 .13	Thiele	1*n* (Phot.)
1902.61	215 .8	2 .79	+0 .8	+0 .34	Thiele	1*n*
1902.64	214 .9	2 .46	−0 .2	+0 .01	Hussey	2*n*
1902.92	214 .5	2 .67	−0 .7	+0 .22	Washn.	2*n*
1902.98	214 .1	2 .50	−1 .1	+0 .05	Scott	2*n*
1903.11	214 .8	2 .37	−0 .5	−0 .07	Bowyer	3*n*
1903.47	217 .1	2 .26	+1 .6	−0 .18	Furner	3*n*
1903.60	216 .0	2 .46	+0 .4	+0 .01	Lewis	4*n*
1903.64	216 .8	2 .36	+1 .2	−0 .07	Doberck	1*n*
1903.69	212 .6	2 .44	−3 .0	+0 .01	Thiele	1*n* (Phot.)
1903.93	215 .1	2 .25	−0 .7	−0 .18	Bowyer	3*n*
1905.05	216 .4	2 .61	±0 .0	+0 .20	Espin	2*n*
1905.21	215 .4	2 .34	−1 .1	−0 .07	Lohse	2*n*
1907.64	217 .8	2 .57	−0 .1	+0 .20	Lau	2*n*
1907.67	216 .3	2 .48	−1 .6	+0 .11	Lap.-Ja.	2*n*
1908.07	216 .5	2 .56	−1 .6	+0 .20	Furner	1*n*
1908.33	218 .5	2 .25	+0 .2	−0 .11	Biesbr.	4*n*
1908.66	215 .4	2 .29	−3 .1	−0 .06	Bowyer	1*n*
1908.66	220 .3	2 .30	+1 .8	−0 .05	Lau	1*n*
1908.75	220 .2	2 .36	+1 .7	+0 .01	Doberck	3*n*
1909.68	218 .8	2 .49	−0 .3	+0 .16	Lap.-Ja.	1*n*
1909.68	220 .4	2 .27	+1 .3	−0 .06	Lau	1*n*
1910.52	219 .7	2 .27	+0 .1	−0 .05	Doolittle	3*n*
1910.80	219 .7	2 .27	−0 .1	−0 .05	Voute	4*n*
1911.67	220 .1	2 .46	−0 .2	+0 .15	Buch.-And.	1*n*
1911.68	217 .6	2 .44	−2 .7	+0 .13	Lap.-Ja.	2*n*
1911.81	221 .1	2 .16	−0 .7	−0 .14	Biesbr.	6*n*
1911.93	222 .9	2 .45	+2 .4	+0 .15	Chapman	1*n*
1912.58	221 .9	2 .24	+1 .0	−0 .05	Chapman	1*n*
1912.73	221 .4	2 .24	+0 .4	−0 .05	Voute	4*n*
1912.73	221 .1	2 .19	+0 .1	−0 .10	Phillips	3*n*
1912.74	221 .4	2 .33	+0 .3	+0 .04	Aitken	1*n*
1912.86	221 .4	2 .22	+0 .3	−0 .07	Doberck	3*n*
1914.67	222 .4	2 .15	+0 .2	−0 .11	Phillips	3*n*
1914.83	221 .8	2 .21	−0 .5	−0 .05	F. W. Brown	4*n*
1914.85	221 .5	2 .05	−0 .8	−0 .21	Leavenw.	4-3*n*

From these 74 observations there were first formed the following seven mean places, the numbers in parentheses indicating the weights ascribed to the various observations. The corrections for precession have been applied, but these are here very small: mean places earlier than 1853.6 are diminished by 0°.01 and those later than 1906.4 are increased by 0°.01.

**Lewis has here 1895.30; there is also an error in the *G.C.*, where the date is given 1894.20

1839.191	192°.29	3″.83	(D1, Σ3, D1 D½, Ma2, D1)
1863.570	198 .82	3 .27	(Δ3, M1, Se1, Ma2, Δ5, Du1, Δ3)
1882.759	205 .49	2 .97	(Du1, S½, Do1, J1, E1, B½, HΣ1, Ha1, Maw1)
1896.229	211 .93	2 .65	(J½, Gl K1, C1, Con1, N1, S½, B1, M1, B½, A1, L½, Do½)
1903.343	214 .70	2 .41	(B1, T⅛, T⅛, Hu1, W½, S½, B1, F1, L1, Do¼, T0, B1, Es½, Lo1)
1910.154	219 .60	2 .30	(L¼, L-J¼, F⅛, Bi 1, Bo⅛, L¼, Do¼, L-J⅛, L⅛, D1, V1, B-A¼, L-J⅛, Bi1, C⅛, C⅛)
1913.630	221 .57	2 .20	(Each observation given weight 1)

These seven places were next plotted and a straight path drawn thru them, the elements of the path being improved by a least-square adjustment with the usual formulas. The final (third) adjustment led to the following values:

$$\left.\begin{aligned} a &= 342^\circ.14 \\ p &= 1''.9583 \\ \mu &= 0''.029423 \\ T &= 1953.006 \end{aligned}\right\} \text{(Mean Equator and Equinox of 1880.0)}$$

The seven mean places are almost perfectly represented by these elements, the $[vv]$ for θ being but 0°.63, and for ρ but 0″.031. When the computed places are compared with the individual observations, we obtain columns four and five of the above tabulation: these show some evidence of curvature of path since positive residuals in distance predominate from 1837 to 1900, but the evidence is hardly as conclusive as could be wished.

If we determine the velocities in the path, regarded as a straight line, we obtain the following results:

	v
1839-1863	0″.0303
1863-1882	0 .0288
1882-1896	0 .0309
1896-1914	0 .0283

There is thus no evidence of a variation in velocity, nor, tho the stars are so rapidly drawing together, is there any evidence of an approach to periastron.

The proper motion of the system, according to Boss, is 0″.106 in 220°.5; the relative motion of *B* with regard to *A*, as found in the present investigation, has the very different value, 0″.029 in 342°.1. In conclusion, it may therefore be said that while it is very probable, and indeed almost certain, that the two components are physically connected, the micrometric measures give but little definite evidence of such a connection. As the relative velocity has remained practically unchanged for a hundred years, it is not to be expected that the character of the motion will soon suddenly change, and consequently frequent observations on this pair are at this time unnecessary.

The following brief ephemeris will probably represent the motion for the next few years:

	θ	ρ
1918.0	224°.40	2″.21
1920.0	225 .76	2 .19
1922.0	227 .16	2 .16

Burnham in 1909 has measured a 12.8 magnitude star, 82″ distant from *A*.

The Flower Observatory,
March 16, 1919.

ASTRONOMICAL OBSERVATIONS IN 1918

MADE BY TORVALD KÖHL, AT ODDER, DENMARK

VARIABLE STARS

(The instrument used is a 3-inch Steinheil, power 42.)

R *Ursae Majoris*[1]

Jan. 3: R invisible
4: id.
16: utmost faint
31: invisible
Feb. 11: id.
Aug. 31: 1 step < k
Sept. 4: 1 step > h
(h seems to be 2 steps
< k, while Hagen
has h = $9^{m}.6$
k = $9\ .9$)
9: =h
Sept. 20: 2 steps > m
29: = l
Oct. 9: $\left\{\begin{matrix} = \\ < \end{matrix}\right.$ m
25: invisible
Nov. 4: id.
9: id.
22: id.
Dec. 22: id.
26: id.
28: id.
31: id.

S *Ursae Majoris*[2]

Jan. 2: S = e
4: 1 step < e
7: id.
15: 3 steps < e
16: id.
31: 1 step > f′
Feb. 8: = f′
11: = f
14: id.
27: = g
Mar. 1: = g
2: id.
3: id.
5: id.
7: 1 step < g
9: id.
17: = g
July 31: 1 step > d
Aug. 10: = d
18: = e
24: 1 step < e
31: $\left\{\begin{matrix}\text{half-way between} \\ \text{e and f}'\end{matrix}\right.$
Sept. 4: 2 steps > f′
9: = f′
12: = f
13: id.
20: = g
27: id.
29: id.
Oct. 8: id.
25: < g
30: invisible
Nov. 3: id.
4: id.
9: id.
22: $\left\{\begin{matrix} > \text{g} \\ < \text{f} \end{matrix}\right.$
24: =f′
Dec. 22: = e
26: id.
28: 1 step < e
31: = e

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[1] Vide the sketch in the *Publications A. S. P.*, No. 175, **30**, 181.

[2] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.

T *Ursae Majoris*[3]

Jan. 2: T 2 steps > g
4: = g
7: 2 steps < g
15: invisible
16: id.
31: id.
Feb. 8: id.
11: id.
14: id.
27: id.
Mar. 1: id.
2: id.
3: id.
5: id.
7: id.
9: id.
17: id.
Aug. 10: = d
18: half-way between d and e
24: = e
31: 3 steps < e
Sept. 4: half-way between g and e
9: 2 steps > g
12: 1 step < g
13: id.
20: 3 steps < g
27: id.
29: id.
Oct. 8: 5 steps < g
25: invisible
30: id.
Nov. 3: id.
4: id.
9: id.
22: id.
24: id.
Dec. 22: = g
26: 2 steps > g
28: 2 steps < e
31: = e

Var. 25, 1913, *Ursae Majoris*

(B. D. + 60° 1412 ($9^{m}.5$) = *f* in the sketch for T *Ursae Majoris.*)

Jan. 2: 2 steps > g
4: = g
7: id.
15: 2 steps > g
16: 1 step > g
31: = g
Feb. 8: 2 steps > g
11: 1 step > g
14: = g
27: 3 steps > g
Mar. 2: 2 steps > g
3: id.
5: id.
7: half-way between e and g
9: e (3) f (2) g
17: 1 step > g
Aug. 10: 1 step < g
18: 2 steps < g
24: 1 step < g
31: = g
Sept. 4: id.
9: $\left\{\begin{matrix}=\\>\end{matrix}\right.$ g
12: 1 step < g
20: 1 step > g
27: = g
29: id.
Oct. 8: 1 step < g
25: 1 step > g
Nov. 3: $\left\{\begin{matrix}<\\=\end{matrix}\right.$ g
9: 1 step < g
22: 1 step > g
24: id.
Dec. 22: 2 steps > g
26: id.
28: id.
31: = g

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[3] Vide the sketch in the *Publications A. S. P.*, No. 22, 4, 63.

S *Persei*[4]

Feb. 13: S = d
Mar. 3: id.
9: = e
Apr. 10: $\left\{\begin{array}{l}< e\\ > f\end{array}\right.$
May 5: = e
Aug. 31: id.

Sept. 9: id.
20: id.
29: id.
Oct. 9: 1 step < e
25: $\left\{\begin{array}{l}\text{half-way between}\\ \text{e and d}\end{array}\right.$
Nov. 4: = e
22: $\left\{\begin{array}{l}=\\ <\end{array}\right.$ e

W *Persei*[5]

Feb. 13: W$\left\{\begin{array}{l}2\text{ steps} > f\\ 5\text{ steps} < e\end{array}\right.$
27: $\left\{\begin{array}{l}\text{half-way between}\\ \text{g and f}\end{array}\right.$
May 5: = f
Aug. 31: 2 steps > n
Sept. 9: = n
20: 3 steps < n

Sept. 29: 2 steps < n
Oct. 9: < n
25: 4 steps < n
Nov. 4: id.
22: < n

R *Aurigae*[6]

May 5: R invisible
Aug. 31: = k
Sept. 9: 1 step < h
20: = h
29: id.
Oct. 9: = g

Oct. 25: = l
Nov. 9: = k
22: $\left\{\begin{array}{l}=\text{g}\\ \text{g seems} < \text{h}\end{array}\right.$
Dec. 22: 1 step > e
28: $\left\{\begin{array}{l}\text{half-way between}\\ \text{e and d}\end{array}\right.$

Y *Tauri*

The comparison stars have been:

A = B. D. + 20° 1095 $(7^{m}.4)$
b = B. D. + 20° 1073 $(8^{m}.2)$

Jan. 2: Y 2 steps > A
4: 1 step > A
7: id.
15: id.
31: = A
Feb. 11: 2 steps < A
27: $\left\{\begin{array}{l}< A\\ > b\end{array}\right.$ nearest b
Mar. 1: 2 steps > b
17: $\left\{\begin{array}{l}< A\\ > b\end{array}\right.$
30: = b

Apr. 10: $\left\{\begin{array}{l}< A\\ > b\end{array}\right.$
Oct. 2: $\left\{\begin{array}{l}=\\ <\end{array}\right.$ A
25: 2 steps < A
30: 3 steps < A
Nov. 9: = b
11: 2 steps > b
24: 3 steps > b
Dec. 22: 1 step < A
26: id.
28: id.

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[4] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 43.
[5] Vide the sketch in the *Publications A. S. P.*, No. 175, **30**, 182.
[6] Vide the sketch in the *Publications A. S. P.* No. 175, **30**, 183.

U *Herculis*[7]

Apr. 10: U invisible
18: id.
27: id.
May 1: id.
4: id.
Aug. 10: = e
24: = c
31: id.
Sept. 3: 2 steps > c
9: 4 steps < a
12: 1 step < a
Sept. 20: = a
29: id.
Oct. 8: 1 step < a
25: half-way between a and c
30: 2 steps > c
Nov. 3: > c
9: half-way between c and d
11: 1 step < c
22: = d
24: id.

SS *Cygni*[8]

Jan. 7, 6^h: SS 3 steps < h
31, 6^h: 2 steps > c
Feb. 1, 7^h: 1 step > c
11, 7^h: = d′
Apr. 18, 11^h: invisible
May 1, 10^h: = h
Oct. 30, 11^h: $11^m.5$
Nov. 9, 9^h: = b
11, 8^h: = c
22, 8^h: invisible
Dec. 22, 6^h: = f
28, 6^h: = g
31, 7^h: id.

R *Coronae*[9]

Mar. 5: a (3) R (1) b
Apr. 10: a (1) R (1) b
18: a (2) R (1) b
27: id.
Aug. 24: 5 steps > a
31: id.
Sept. 4: 5 steps > a
9: id.
12: 4 steps > a
20: id.
29: id.
Oct. 8: id.

W *Pegasi*[10]

Jan. 2: W = h
7: id.
16: $\left\{\begin{array}{l}> g\\ < f\end{array}\right.$
17: id.
31: 1 step > c
Feb. 2: = f
14: 2 steps > f
Aug. 31: = n
Sept. 4: 1 step > n
9: 1 step < n
12: < n
Sept. 20: 3 steps < n
27: invisible
29: id.
Oct. 9: id.
25: id.
27: id.
Nov. 9: id.
22: id.
Dec. 22: = h
28: half-way between g and h
31: = h

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[7] I have used the sketch in the *Publications A. S. P.*, No. 106, **18**, 52, but have added two small neighboring stars, *g* at *a* and *h* at *f*, both northward.

[8] Vide the sketch in the *Publications A. S. P.*, No. 141, **24**, 109.

[9] Vide the sketch in the *Publications A. S. P.*, No. 175, **30**, 184.

[10] Vide the sketch in the *Publications A. S. P.*, No. 141, **24**, 109.

TV *Cygni*[11]

Jan. 7: TV$\left\{\begin{matrix}< b\\> c\end{matrix}\right.$
31: id.
Feb. 11: = c
Apr. 27: id.
May 1: 2 steps > c
Nov. 9: 2 steps > d
Dec. 22: $\left\{\begin{matrix}\text{half-way between}\\\text{b and c}\end{matrix}\right.$
31: 1 step > c

A New Variable Star

While observing the region about *α Leonis* on March 6th, 1918, and comparing two Carina-plates, No. 51 (April 18, 1915) and No. 60 (April 15, 1916) I found a great disagreement concerning the star V = B. D. + 14° 2194 ($9^m.5$), which now is Var. 5, 1918 *Leonis* (A. N. 4937). The comparison-stars have been:

q = B. D. + 14° 2190 $8^m.8$
z = B. D. + 14° 2197 9 .4
y = B. D. + 14° 2199 9 .7
p = B. D. + 14° 2195 10 .2
The magnitudes according to my own judgment.

Mar. 6: V 3 steps < y
7: < y
9: < y
17: 2 steps < y
30: 2 steps > z
Apr. 5: 3 steps > z
10: *q* (1) v (2) z
11: 4 steps > z
17: > z
18: *q* (4) v (5) z
23: id.
27: id.
Apr. 28: id.
29: id.
May 1: id.
2: id.
4: id.
5: q (1) v (1) z
6: id.
7: id.
12: $\left\{\begin{matrix}=\\<\end{matrix}\right. q$
Oct. 2: 1 step < *q*
31: $\left\{\begin{matrix}=\\>\end{matrix}\right. z$
Nov. 12: 2 steps > y
Dec. 31: z (3) v (1) y

Several other stars, suspected of variation, have also been watched in the year 1918. My observations on *Nova Aquilae 3* have been sent to Cambridge, Mass., in response to Bulletin 661 from Harvard College Observatory. On this occasion, reviewing some comparison-stars near 5 *Aquilae*, I found that the star B. D. ÷ 1° 3546 ($9^m.5$) *was not visible.*

Large Meteors

Fireballs have been observed from Denmark on the following dates: May 4th, 16th, July 6th, August 11th (4 observations),

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[11] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 43.

August 13th (3 observations), *September 27th* and November 12th. Already several years ago I noted September 27th as a "Fireball-day."

The Carina-Meteor catalog has now reached the number of 6568 meteors observed from stations in Denmark and surrounding countries from 1875 to 1918 inclusive.

From August 12th to 17th, inclusive, astronomical lectures were held at the Carina-Observatory in Odder, and besides these thirty-six popular lectures were given this year at different places in Denmark. The entire number of my lectures in the course of many years is now 1429.

By the aid of a 78$^{\mathrm{mm}}$ Darlot lens, Mr. *J. Skakke* has in this year photographed several regions of the heavens.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1919

By Malcolm McNeill

Pacific "Summer Time" of the phenomena may be obtained by adding one hour to Pacific Time.

PHASES OF THE MOON, PACIFIC TIME

First Quarter....	July	4,	7^h17^m P.M.	First Quarter...	Aug.	3,	12^h11^m P.M.
Full Moon......	"	12,	10 2 P.M.	Full Moon.....	"	11,	9 39 A.M.
Last Quarter....	"	20,	3 3 A.M.	Last Quarter...	"	18,	7 56 A.M.
New Moon.....	"	26,	9 21 P.M.	New Moon....	"	25,	7 37 A.M.

The Earth is in aphelion, that is, reaches its greatest distance from the Sun July 3rd, 2 A. M. Pacific Time.

Mercury is in good position for evening observation during the last few days of June and the first half of July. On July 1st the planet does not set until nearly an hour and a half after sunset, and the interval does not diminish much until after the middle of the month. Greatest east elongation occurs on July 18th, quite a large one—nearly 27°, as aphelion is only a few days distant; but the motion of the planet in its orbit causes it to be a considerable distance south of the Sun, thus causing a shortening of the interval between sunset and the setting of the planet before the date of greatest elongation. Conjunction with the Sun occurs on August 15th, and the planet becomes a morning star, nearly reaching greatest west elongation by the end of the month. The planet then rises about an hour and a half before sunrise, thus being in fine position for morning observation. On the evening of July 6th *Mercury* is a little more than 1° north of *Neptune*.

Venus is in fine position for evening observation, being above the horizon about two and one-half hours after sunset on July 1st, but the interval diminishes to only a few minutes by the end of August. It reaches greatest east elongation on July 4th, being then 45° from the Sun, but as in the case of *Mercury*, the planet's motion is also southward in greater degree than the motion of the Sun, causing a rapid diminution in the interval between sunset and setting of the planet. *Venus* will be at its maximum brightness during the two months, the greatest brilliancy occurring on August 7th, about half way between the times of greatest elongation, July 4th, and of inferior conjunction with the Sun, September 12th. It will, after the Sun and Moon, be by far the brightest object in the sky and may be seen in broad daylight for some weeks about the time of greatest brilliancy. Its "stellar magnitude" during the last week in July and the first half of August will be −4.2, that is, it will be nearly fifty times as bright as an ordinary first magnitude star. *Regulus*, the brightest star in *Leo*, is not greatly different in brightness from a normal first magnitude. *Venus* passes a short distance to the north of this star on July 5th.

Mars passed conjunction on May 9th, and by July 1st it has attained a sufficient apparent distance from the Sun so that it rises about an hour before sunrise. It is still at nearly its minimum brightness and will therefore hardly be visible in the morning twilight except under unusually favorable weather conditions until some time after July 1st. By August 1st it rises about two hours before sunrise, and at the end of the month nearly three hours before. It will therefore be easily visible thruout August. During the two months it moves about 44° eastward from the eastern part of *Taurus* thru *Gemini* into *Cancer*. During early August it is south of *Castor* and *Pollux*, its nearest approach to *Pollux*, the southern and eastern one of the two stars, being about 6°, a little more than the distance between the stars. This occurs on August 12th.

Jupiter is rather too near the Sun during July and August for easy observation, coming into conjunction with that body on July 20th. On July 1st it sets about an hour after sunset, and on account of its great brightness may be seen for a few days in the evening twilight, but it is soon lost in the Sun's rays, and after passing the Sun at conjunction it becomes a morning star. Shortly after August 1st it rises an hour before sunrise, this interval increasing to nearly three hours by the end of the month.

Saturn is still an evening star on July 1st, but its apparent distance from the Sun is rapidly diminishing. At the beginning of July it does not set until two and a half hours after sunset, so it is still in fair position for evening observation. By August 1st it sets only about an hour after sunset and will therefore not be an easy naked-eye object, as it is not nearly as bright as *Jupiter*. It reaches conjunction with the Sun on August 25th, and becomes a morning star, but does not attain a sufficient distance for early morning visibility until some time after the end of the month. During the two months it moves about 7° eastward in *Leo*. Toward the end of July it is very close to *Regulus*, the brightest star of the constellation, passing about 1° to the north of it on July 30th.

Uranus is drawing into fair position for observation, rising about three hours after sunset on July 1st, and about an hour before sunset on August 31st. It comes to opposition with the Sun on August 23rd, and is then above the horizon the entire night. It moves about 2° westward in the constellation *Aquarius* during the two months.

Neptune reaches conjunction with the Sun on August 2nd, changing from an evening to a morning star.

THE BINARY STARS[1]. A REVIEW

By E. E. Barnard

The best contribution to the general literature of double stars in recent years is the admirable volume on the subject by Robert Grant Aitken of the Lick Observatory. The presentation of this work has fallen into worthy hands indeed and the result is a book that can be read with much pleasure as well as with profit.

Professor Aitken has given us a work which is not only of permanent value for instruction but is of very deep interest because of the historical information it contains. It will be valuable to the general astronomical reader, as it gives an interesting account of the early history and development of double-star work. To the double-star observer himself it is an excellent source of information concerning the first observers of these stars, about whom he has probably known little enough. Perhaps even some of the regular double-star observers will be surprised to learn how slow the earlier astronomers were to grasp the nature and importance of these objects.

The first double stars discovered, such as α *Centauri*, *Castor*, etc., were, as would be supposed, found by accident. It is with surprise, however, that we read of the subsequent treatment of these most interesting and important bodies by the early observers. To them a double star was simply two stars seen nearly in the same line of sight and not physically connected in any way and probably vastly distant from each other. Especially was this thought to be the case where one of the stars was brighter than the other. This strange lack of insight into their true nature continued for upward of a hundred years after the first discoveries were made. A strong interest was taken in them, however, and they were sought for and carefully observed, not with the belief that they were physically connected (indeed, it was necessary that they should have no physical connection whatever), but with the hope that their measurement offered the best means of determining stellar parallax. Even Herschel made a special search for these stars, at first with no other idea of their importance than for the determination of stellar parallax.

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[1] Robert Grant Aitken, *The Binary Stars*, 1918, 316 pages. Douglas C. McMurtrie, 2929 Broadway, New York. Price $3.15.

The first double stars discovered were γ *Arietis* in 1664 and α *Crucis* and α *Centauri* in 1685 and 1689 respectively. It was not until 1767, however, when it was shown by John Michell that such stars were probably physically connected systems, that they became of general interest as double stars.

It was in the latter part of the eighteenth century that thru the investigations of Christian Mayer, who formed the first catalog of double stars, and of Sir William Herschel, who could not remain long in error, that these stars were ultimately recognized as physically connected systems. Herschel was finally convinced by his own measures that they were actually physically connected, for in his observations he found that in some cases there really was a change in the relative positions, but not such as would be due to parallax. Thus, after great delay, the true nature of these objects became known and their intelligent study as double stars began. They were now sought for and observed for the investigation of their motions about each other. The fallacy of their observation for parallactic displacement was at last recognized.

Professor Aitken pays a fine tribute to Burnham and the work that was done with the six-inch Clark refractor, work which in many ways was revolutionary in the fact that it showed that there was no end to the discovery and observation of double stars, even with the limited means at his disposal. We learn that after the discovery of new double stars seemed exhausted with much larger instruments, Burnham discovered 451 new pairs with the famous six-inch Clark refractor and set a record of the highest order, which he maintained in all the subsequent work that he did with this instrument and the greater telescopes which he used later on.

It is pleasant reading to learn of the great work in double-star astronomy by those who preceded Burnham, and by those who were his contemporaries. Such men as the Herschels, the Struves, Dawes, Hough and others, and especially Dembowski, to whose skill and help Professor Burnham bears loving testimony in one of his books, were among the men who built up a solid foundation for the double-star astronomy of today. It is almost pathetic to learn of the trials of the earlier observers, who were so seriously handicapped for the want of proper equipment with which to carry on their chosen work. One of these men was Baron Dembowski, who worked with a five-inch telescope with no driving clock or means of determining position angles (which he derived from measures of differences of right ascension and declination) until 1859, when he obtained a seven-inch refractor, fully equipped with micrometer and driving clock.

It appears that Wilhelm Struve in 1824 was the first observer to actually use clockwork for driving his telescope, tho it seems that a telescope driven by a clock was presented to the king of France in 1757, who doubtless did not sit up to verify the statement that "it would follow a star all night long."

Chapter III contains a discussion of the best methods of observing, which is of special value coming from one with such a wide and successful experience with the micrometer. The method of determining the parallel, the value of a revolution of the micrometer screw and the best way of observing double stars are successively given, with an example of the method of recording the observations, the best form of observing book, etc. When observing position angles the author finds that where the angular distance is small or the stars differ much in brightness, it is best to bisect the stars with a single movable wire instead of placing them between two wires close together, as some observers prefer to do. He emphasizes the importance of using only good nights for observing double stars, as observations made on poor nights often lead to annoyance and error.

It is recommended that instead of estimating the actual magnitudes of the components of a double star, their difference of magnitude be recorded, which seems a very satisfactory method and subject to greater exactness. The actual magnitude of each star can then be determined from the catalogued magnitude of the brighter one or of the combination.

An interesting discussion of the separating power of a telescope is given. After discussing the results obtained by Lewis, using Dawes' formula

$$\text{Separating power} = \frac{4''.56}{a \text{ (aperture in inches)}}$$

Aitken finally, from measures by Burnham, Hussey and himself, deduces the following formula for the thirty-six-inch refractor.

Equal bright pairs $\frac{4''.3}{a}$, mean magnitudes 6.9 and 7.1.

Equal faint pairs $\frac{6''.1}{a}$, mean magnitudes 8.8 and 9.0.

His experience, however, is that under ordinary observing conditions, the angular separation of the pairs measured should be nearly double the theoretical limit.

His remarks on diaphragms are interesting. He does not find that a diaphragm improves a good object glass and the views of both Schiaparelli and Burnham are opposed to the reduction of aperture. Really, tho Professor Burnham did not believe in reducing the aperture of the object glass, he often used a small diaphragm over the eyepiece, thus cutting down the beam before it entered the eye. This is a method that is often very useful in reducing the glare about a star. A discussion arose some time ago over this question as to whether a diaphragm over the eyepiece caused a reduction in the separating power of the object glass. I believe the question has never been definitely settled, tho it would seem, since the reduction of the beam of light occurs after the image is really formed, that it would not necessarily affect the separating power.

Valuable information is given with respect to the use of eyepieces. Professor Aitken's experience with thirty-six inch shows that it is better to employ low powers when the conditions are poor, for every increase of power increases the bad effects of poor definition. With respect to the best magnifying powers to use on the large refractor he says, "With the thirty-six-inch telescope my own practice is to use an eyepiece magnifying about 520 diameters for pairs with angular separation of 2" or more. If the difference is only 1", I prefer a power of 1000 and for pairs under 0".5, I use powers from 1000 to 3000 according to the angular distance and conditions. Closeness and brightness of the pair and the quality of the definition are the factors that determine the choice. Very close pairs are never attempted unless 1500 or higher powers can be used to advantage."

Systematic errors of observation—especially in position angle—are treated of and suggestions offered for their elimination. The method employed in some experiments by MM. Salet and Bosler in 1908 with a small total reflecting prism between the observers' eye and the eyepiece seems to satisfactorily eliminate systematic error in the observed position angle. The error seems to be greater when there is a considerable difference in the magnitudes of the two stars, tho the position with respect to the horizontal, even with stars of equal magnitude, is a source of error. In this connection it may not be out of place for the reviewer to give here an account of some experiments recently made by him with the forty-inch telescope of the Yerkes Observatory. The double star, Krueger 60, consists of two stars which differ by about one and a half magnitude. At present their relative position is such that when east of the meridian the small star is uppermost and when west it is the lower of the two. The star was observed on seventeen nights in the fall of 1916, both east and west of the meridian, in immediate succession on the same night. The distance between the components at the time was less than $2''.5$. On each occasion the stars were carefully placed (by turning the head) so that when bisected the two were exactly in the vertical to the line between the eyes, a precaution that should always be taken and which tends to diminish the systematic error in such observations. Following are the results:

	East of Meridian (Small star up)	West of Meridian (Small star down)
P.A.	62°.55 (17 nights)	62°.71 (17 nights)

The difference is $(U-D) = -0^\circ.16$. The different sets were discordant in some cases by as much as 1° to 1½°. When the proper precautions are taken (at least in the case of the present observer) there does not seem to be any serious error in the bisections for position angle, whether the small star is above or below, for the above difference is too small to mean anything. The measures seem to be easier when the small star is the lower. In respect to the question whether in bisecting the stars for position angle the line between them should be perpendicular to the line between the eyes or parallel with it: the reviewer finds that his measures are more consistent and easier when the stars are in the vertical line.

An interesting result is shown by comparing the measures of distances with the twelve-inch and the thirty-six inch telescopes. It appears that with the smaller instrument the measures of close stars give larger distances, while with distances of 4″ or more this difference disappears.

A short discussion of the results of photographic measures show much in favor of the method for exactness where the conditions of distance and relative brightness of the components are favorable. But the closer pairs and those where much difference of magnitude exists, are not suitable for photographic measurement.

Chapter IV is devoted to a valuable description of the methods of determining the orbits of binary stars. A completely worked-out example is given in the case of the binary star, *Aitken 88*. This should be of very great help to the beginner in such work. The methods suggested and employed by Moulton, Comstock, Russell and others are discussed.

Chapter VI, in like manner, gives a full statement of the method of determining the orbits of the spectroscopic binaries from their radial velocities.

A brief account is given of the systems where one component is invisible, the two most famous examples of which are *Sirius* and *Procyon*, whose companions were subsequently discovered visually by Clark and Schaeberle respectively. Other dark companions, to *β Orionis*, *α Hydrae*, *α Virginis*, *ζ Cancri* and others, have been suspected to exist but so far they have not been found.

Chapter IX is devoted to a most interesting description of binary systems of special interest, including *α Centauri*, whose orbits by Roberts, See, Doberck and Lohse are in good accord. Thru the measures of the radial velocity by Wright in 1904 and the known elements of the orbit, Wright has determined the parallax of this system and gets results in close accord with direct determinations of its parallax.

In Chapter X Professor Aitken gives an important statistical study of the distribution of the visual double stars in the northern sky, which contains a number of tables showing the distribution of these stars by magnitudes, by angular distances, by spectral types, etc.

An important chapter (XI) contains a valuable discussion of the various theories of the origin of the binary stars. Professor Aitken finally concludes that when everything is considered, the fission theory of their origin is, perhaps, the most satisfactory, tho there are very serious difficulties about accepting it without reserve.

One of the most interesting and instructive parts of this most interesting book is that contributed by Dr. J. H. Moore on the radial velocity of a star. This is very clearly written and to those who are not familiar with the work of the spectroscope is of the utmost value. One statement that makes more evident the difficulties that beset this wonderful instrument—the spectroscope—is that "When stellar spectrographs of three prism dispersion are used in conjunction with large refractors or reflectors, the combined instrument delivers to the photographic plate probably less than two per cent. of the light incident upon the telescope objective." Yet, with all the drawbacks that are so clearly set forth in Dr. Moore's valuable article, results that seem almost like magic are obtained when all the multitudinous precautions are taken into account. It is a happy combination indeed that places before the reader two such splendid accounts of the results of visual and spectroscopic observations of the binary systems of stars. When one has read Dr. Moore's account of the sources of error in the spectroscope and the ingenious devices that have been brought to bear upon their prevention or elimination, one can but express the sincerest admiration for the work of those who have made the spectroscope the magician's wand that it now seems to be.

Yerkes Observatory, E. E. Barnard.
Williams Bay, Wisconsin,
May 15, 1919.

PAPERS AND ABSTRACTS OF PAPERS TO BE PRESENTED AT THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC AT PASADENA, JUNE 19-20, 1919.

As already announced in these Publications, the Astronomical Society of the Pacific will meet with the Pacific Division of the American Association for the Advancement of Science at Pasadena, on June 19-21. Two sessions will be held for the presentation of scientific papers, both at Throop College, the first from 10 to 12 on Thursday morning, June 19th, the second from 9:30 to 12 on Friday morning. At the second session a number of papers of interest to physicists as well as astronomers will be read and the members of the Physical Society (which holds but one session, Thursday morning) are specially invited to be present. Throop College invites all members of the Division and affiliated societies to partake of luncheons served in the college dormitory on Thursday and Friday, June 19th and 20th.

No afternoon meetings will be held by the separate societies, but all members are invited to attend the general meetings of the Division and participate in the two Symposia which have been arranged. The first, on Thursday afternoon, will be on *The Exploration of the North Pacific Ocean.* Eight men, qualified by experience to treat of them briefly and succinctly, will introduce as many topics of great scientific and economic interest, and a general discussion will follow. The general subject for Friday afternoon is *Scientific Education in a Democracy.* President Scherer of Throop College will present the opening paper on *The Dependence of a Community on Scientific Experts,* and will be followed by six other speakers introducing such topics as *The Responsibilities of the Scientist, Must Learning be Mediocre in a Democracy?* etc. It is hoped that many members will take part in the discussions of all of the papers.

On Thursday evening the retiring president of the Pacific Division, Dr. D. T. McDougal, will deliver his address on *Growth of Organisms.* Following the address a public reception will be held. On Friday evening, Dr. S. D. Townley, of Stanford University, will give a public address on *Earthquakes on the Pacific Coast of North America.* These evening meetings will be held in the Palm Room of the Hotel Maryland.

An excursion to the summit of Mount Wilson is planned for Saturday, June 21st. Automobile stages will leave the Observatory offices at about 10 A. M. and will return to Pasadena in season for dinner. Delegates wishing to remain overnight on the mountain may secure quarters at the Mount Wilson Hotel by making arrangements in advance. An opportunity will be afforded for observation with the 60-inch telescope and it is probable that the 100-inch reflector may be utilized to some extent.

On the following pages the astronomical papers to be presented are given in full, or in the form of abstracts of greater or less length. The arrangement here is one of convenience and does not indicate the order of the actual program. Some of the papers may be read by title only, to afford time for discussion of the others.

STEREOSCOPIC PHOTOGRAPHS OF THE SOLAR ATMOSPHERE

BY GEORGE E. HALE

An illustrated account of methods and results, indicating the precaution necessary to avoid pseudo-effects.

ARE THE WAVE-LENGTHS OF THE ATMOSPHERIC ABSORPTION LINES VARIABLE?

BY CHARLES E. ST. JOHN AND HAROLD D. BABCOCK

In 1915 Professor Perot published a short account of observations he had made upon wave-lengths of lines in the absorption spectrum of the Earth's atmosphere. Using solar lines as reference standards he found that oxygen lines in the B group appeared to undergo a diurnal variation of wave-length amounting to a change of about 0.030 A. Recent observations made both on Mount Wilson and at Pasadena by two distinct methods, have failed to confirm the supposed variation.

ON RADIATION AND THE AGE OF STARS

BY HARLOW SHAPLEY

The long-standing disagreement between physical astronomy and geology as to the duration of solar radiation and the consequent age of the Earth, has as its basis on the physical side the assumption that the Sun's heat, flowing uniformly at the observed rate in all directions, comes from recognized sources—from gravitational contraction (generally admitted to be the most important source of energy), from in-falling meteorites, radioactivity, etc. In the case of the Sun these sources can supply for only a few million years the observed flow of heat, and in the case of the truly gaseous stars the total duration of the giant stage is limited to some thousands of years, according to computations by Eddington and others.

The data of geology, however, particularly the recent work on rhythms in denudation and sedimentation and on the radioactivity of rocks, are decidedly opposed to a short-time scale for the Sun and Earth. Similarly for the giant stars, the recent results from globular clusters and Cepheid variables appear decisive against former estimates of age. For instance, the period-luminosity correlation for Cepheids, as well as the observed constancy of their periods, would be impossible if the source of radiant energy for these giants is mainly gravitational. The dimensions now assigned to the galactic system, the distribution and stellar content of globular clusters, and the fact that their star-colors are independent of relative distance, are all likewise opposed to the short-time scale. It appears from present geological and astrophysical evidence that the duration of the life of stars is probably several hundred times the interval given by the older physical theory.

The discord between the data of observation and the theory that gravitational contraction is the chief source of energy may possibly be accounted for in two different ways; but either of the following hypotheses would encounter some serious difficulties (perhaps not insuperable) with accepted physical properties of matter.

(1) If the radiation from the Sun and stars is actually greater in the direction of the Earth and other celestial bodies than in "empty" directions, then the amount of radiation measured at the Earth's surface has led us to infer a dissipation of solar energy that is too high and to deduce a life for Sun and stars that is too short. Such a hypothesis need involve only recognized sources of energy, and it would alleviate the difficulty with the time scale, would point to a better conservation of radiant energy, and might clear up some outstanding astronomical phenomena (altho simpler explanations may be found later). The supposition, however, of radiation wholly restricted to solid angles subtended by matter, altho in some respects preferable from the standpoint of a corpuscular theory of radiation, is hardly tenable because of observed phenomena of planetary temperatures and for other reasons. The supposition that radiation is merely somewhat concentrated between bodies appears to avoid most of these difficulties.

(2) If, as generally accepted, radiation flows uniformly in all directions, the amount of energy being dissipated from Sun and stars is so great that sources hitherto undiscovered must be invoked. Various expedients have been suggested, such as sub-atomic energy and the cancellation of mass. Perhaps a strong point in favor of such an interpretation is the probability that the very exceptional conditions within a star considerably modify the operation of ordinary physical laws for which we know the behavior at moderate temperatures only; and probably the greatest difficulty with this view is the necessity that the hypothetical source of internal energy must supply heat at just the rate required for radiation, in a manner similar to that of the gravitational contraction of a gas.

But whatever the solution of the energy problem and its significance for theories of radiation, on the basis of existing astronomical evidence it now appears that the disagreement between the long- and short-time scales must be decided in favor of an exceedingly prolonged history for sidereal systems, permitting a relatively slow evolutionary development for stars and planets.

THE SPECTRUM OF RU CAMELOPARDALIS

BY A. H. JOY

RU Camelopardalis ($7^{h}10^{m}.9, +69°54' : 1900$) is one of the variable usually classed among the Cepheids altho its light curve has some peculiarities which have called for special consideration. The range of light variation is 0.9 magnitude and the curve is symmetrical with a period of 22.2 days. The minimum is rather sharp and shorter in duration than in the case of the normal Cepheid.

Shapley, in an extended investigation[1], has studied the light curve and suggests that the variation in light may be due to the rotation of a single ellipsoidal body.

Four spectrograms of the star have been secured with the 60-inch reflector and the single-prism spectrograph with a camera of seven inches focal length.

Plate	Date	G. M. T.	J. D.	Phase From Min.	Hydrogen Lines
7873	1919 Feb. 13	$19^{h}.3$	242 2003.8	2.8 days	Bright
7971	Mch. 17	19 .9	2035.8	12.6 days	Dark
8019	Apr. 9	16 .9	2058.7	13.3 days	Dark
8122	Apr. 20	17 .0	2069.7	2.2 days	Bright

The phases are computed from the elements of Luizet[2] Min. = 2417610.96 +22.172 days.

The unusual and unexpected character of the spectrum for a variable of short period calls for especial comment. It shows all the general characteristics of type R. The four variables of this type with known period are all long-period variables, the average for the four being 396 days, and have a large range of light variation. The maximum strength of the spectrum lies between λ 4737 to λ 4850, and the characteristic carbon absorption at λ 4700 is clearly marked altho not prominent. The *g* group at λ 4308 shows strong absorption about equal to that of type Ko. The spectrograms are all well exposed and the density is good as far as λ 4215, where the light is sharply cut off by the carbon absorption band.

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[1] *Laws' Observatory Bulletin*, No. 21, p. 71.

[2] *A. N.* 4614.

Above this point the spectrum is very weak altho it can be seen farther to the violet in all cases, and one plate can be measured to λ 4000.

It is of interest to note that the plates taken at minimum of light, assuming that the elements are correct, show bright hydrogen lines while those at maximum show the usual absorption lines. Hβ, Hγ, and Hδ are all bright with strength decreasing from red to violet contrary to variables of type Md. Two of the R-type long-period variables mentioned have been observed at Harvard[1] to have Hβ and Hγ bright, presumably at maximum.

The absorption lines of hydrogen are of about the same strength as in type G8. There may be a number of bright lines in the spectrum other than those of hydrogen but this is as yet uncertain.

Preliminary measures show that the velocity is variable with the maximum velocity of approach at maximum of light as in the case of the Cepheid variables, the range being about 45 km. This evidence appears to be opposed to the suggestion that the variation of light is the result of the rotation of a single ellipsoidal body. The bright hydrogen lines give larger negative velocities than the absorption lines at minimum of light, their behavior thus corresponding to that well known in the case of stars of type Md.

So far as may be judged from these spectrograms of rather low dispersion the character of the lines other than those of hydrogen is very similar to that of the lines for typical Cepheids, and the strength of the enhanced lines indicates that the star is intrinsically very bright. The lines are sharp and show no marked variation between maximum and minimum of light.

INFLUENCE OF COLOR IN THE DETERMINATION OF MAGNITUDES

BY FREDERICK H. SEARES

It has long been recognized that stellar magnitudes determined by visual methods depend upon the color perception of the eye of the observer. Similar differences arising from the selective absorption exercised by the glass of the objective or the silvered surface of the reflector affect photographic magnitudes. In certain cases the effect is so large that a comparison of results is meaningless unless the colors of individual stars are known.

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[1] *H. C.* 145, p. 3.

A SYSTEM OF PHOTOGRAPHIC MAGNITUDES FOR THE SELECTED AREAS

BY FREDERICK H. SEARES

The normal scale has been established for each of Areas Nos. 1 to 139 separately. The reduction of the results to a uniform zero point (with which this communication is mainly concerned) has been accomplished by comparisons with the pole. To increase the precision and at the same time to afford an indication of the consistency of the results, the principles underlying triangulation operations have been applied.

PHOTOGRAPHS OF NEBULAE

BY FRANCIS G. PEASE

A series of lantern slides will be shown, illustrating remarkable nebulae recently photographed with the Mount Wilson 60-inch reflector.

THE VARIATION IN SUN-SPOT ACTIVITY DURING THE PRESENT CYCLE

BY SETH B. NICHOLSON

The variation in sun-spot activity during the present cycle has been quite normal in character. Maximum occurred in the latter part of 1917, a little over four years after the previous minimum. There have been several spots large enough to be seen without a telescope. Two that appeared during 1917, in February and August, respectively, were among the largest ever recorded.

THE RELATION BETWEEN THE SIZE OF A SUN-SPOT AND THE STRENGTH OF ITS MAGNETIC FIELD

BY SETH B. NICHOLSON

A definite relation has been found between the size of a sun-spot and the strength of its magnetic field. A curve showing this relation will be presented.

THE STRUCTURE OF THE EMISSION BANDS IN THE SPECTRUM OF NOVA AQUILAE NO. 3

BY W. S. ADAMS AND A. H. JOY

The spectrum of *Nova Aquilae* as photographed in February and March shows but little change when compared with that of November, 1918. The nebular bands are stronger relative to those of hydrogen but the structure within the bands is closely the same as on the photographs taken in the late autumn. Apparently the form of these bands, therefore, represents a fairly stable condition, and it is of interest to learn whether their structure is the same for the different elements.

The bands upon which measurements were made are Hγ, 4363, 4580 to 4700, Hβ, 4959 and 5007. The band Hε is present but is too weak for measurement upon our recent photographs. All the bands show some characteristics in common, being bounded sharply on the violet edge by a bright maximum and having a number of absorption lines distributed thruout their extent. The red edges are defined by what appears to be an absorption line, but beyond this line is a small bright area which no doubt belongs to the band. The effect is seen most clearly in the case of 4363, where this bright "knob" is clearly double.

The following measures show the displacements in angstrom units of the more prominent features of these bands. The assumed normal positions of the bands are as follows: 4340.6, 4363.4, 4640, 4685.7, 4861.5, 4959.0, 5006.9. The displacements are reduced to the Sun and are corrected for the radial velocity of the star. The values for 4640 and 4686 are uncertain on account of the character of the bands. The red portions of the bands Hγ, 4640 and 4959, are overlapped by the bands following and no measures are possible. All of the maxima measured are bright.

	Hγ	4363	4640	4686	Hβ	4959	5007
Vi. edge bright band	−25.6	−25.8	−27	−28	−28.6	−29.5	−29.7
Maximum	24.9	24.9	25	27.1	27.5	28.1	28.4
Absorption line	20.1	20.9	21	22.4	23.8	....	....
Absorption line	17.0	16.8	16	18.1	18.7	19.5	18.6
Maximum	8.5	9.2	..	....	....	10.7	10.3
Absorption line	6.2	6.2	6	6.4	7.1	7.8	8.2
Maximum	4.9	4.5	..	4.3	4.9	5.2	....
Absorption line	....	− 0.3	..	− 1.5	−1.2	0.0	0.0
Maximum	....	+ 4.9	..	....	+ 3.2	+ 4.4	....
Absorption line	....	6.2	..	....	8.2	....	+ 8.7
Absorption line	....	8.6	..	+ 8.5	....	....	10.3
Absorption line	....	13.6	..	....	14.7	....	13.7
Absorption line	....	18.8	..	....	22.1	....	22.1
Maximum	....	23.4	..	....	25.0	....	25.6
Red edge bright band	....	24.0	+26	25.7	26.3	....	27.2
Absorption line	....	+24.9	..	+28	+28	....	+29

It is clear from this comparison that the structure repeats itself in the successive bands, with the displacements from the normal positions proportional to wave-length. The principal value of this result is to show that the absorption lines are due to the elements producing the bright bands and not to foreign elements with lines greatly displaced.

EIGHTEEN STARS WITH SPECTRA SIMILAR TO THOSE OF THE CEPHEID VARIABLES

BY W. S. ADAMS AND A. H. JOY

In a communication to the *Proceedings of the National Academy of Sciences* for May, 1918, we called attention to five stars with spectra resembling strongly those of the Cepheid variables. Observations made since that time have added considerably to their number, and we believe a publication of the list will be of interest to those engaged in determinations of radial velocity and perhaps to variable star observers as well.

The principal characteristics of Cepheid spectra are well-known. Most of them are of the general type F5 to G0 with narrow, sharply defined metallic lines. The hydrogen lines, however, are much stronger than in normal spectra of this type, and the enhanced lines are quite abnormal, having several times the intensity which they possess in stars such as the Sun. In particular, attention may be called to the following enhanced lines, which are also very prominent in the spectrum of the chromosphere and in such stars as α *Cygni.*

4077 Sr 4215 Sr 4233 Fe 4246 Y 4290 Ti: 4375–
4385 Fe 4534 Ti: 4584 Fe.

As has been shown by Shapley and by Adams and Joy the intensities of the hydrogen and the enhanced lines vary with the light of the star, being stronger at maximum of light.

In the following table are given the stars with spectra having Cepheid characteristics. The successive columns give the number of the star in Boss's catalog, its name, visual magnitude, spectral type according to the Harvard observers, proper motion, galactic latitude, and spectral type according to our own determinations. It is of interest to note that four of the stars are marked F8p by the Harvard observers.

			m	Harv. Sp.	μ	b	Spectrum
Boss	619	14 Persei	5.6	F	0".004	−14°	F9
	772	α Persei	1.9	F5	0 .039	− 5	F5
	1074	58 Persei	4.5	G	0 .025	− 4	G1
	1606	ψ^1 Aurigae	5.1	K	0 .014	+17	K3
	1839	δ Can. Maj.	2.0	F8p	0 .005	− 7	G1
	2065	ξ Puppis	3.5	G	0 .007	+ 2	G6
	2153	ρ Puppis	2.9	F5	0 .100	+ 5	F6
	4443	β Draconis	3.0	G	0 .016	+32	G1
	4707	45 Draconis	5.0	F8p	0 .011	+24	F8
	5187	o^2 Cygni	4.0	K	0 .002	+ 6	G7
	5197	α^1 Capricorni	4.6	G	0 .015	−26	G1
	5229	γ Cygni	2.3	F8p	0 .003	+ 1	F9
	5255	41 Cygni	4.1	F5	0 .010	− 6	F6
	5431	ξ Cygni	3.9	K5	0 .007	− 3	K4
	5676	α Aquarii	3.2	G	0 .015	−43	G0
	5804	5 Lacertae	4.6	K5	0 .021	−10	K2
	5931		5.6	G	0 .009	− 4	G0
	6135	ρ Cassiopeiae	4.8	F8p	0 .007	− 5	G5

The spectra of these stars have been compared directly with such typical Cepheids as δ *Cephei* and ζ *Geminorum*, and the following stars have been found to have spectra which are nearly identical with them:

Boss 619, 772, 1074, 2153, 4443, 4707, 5197, 5229, 5255, 5676, 5931. The three stars 1606, 5431 and 5804 show spectra of the K type but with strong Cepheid characteristics. The hydrogen lines, for example, in these stars correspond to the spectral types G5, G5 and G3.

In addition to the similarity of spectral type these stars resemble the Cepheid variables both in their extremely small proper motions and their low galactic latitudes. With the exception of Boss 2153 there is no star in the list with a proper motion exceeding 0".040, and there are but two stars with galactic latitudes greater than 30°.

The following stars in the list have been found to have variable radial velocities from observations at the Lick Observatory:

Boss 1606, 1839, 2153, 5187, 5431

Mount Wilson observations of Boss 1074 when compared with those published by the Lick Observatory indicate that this star also has a variable velocity. Accordingly six of the eighteen stars in the list have this characteristic, and it is possible that others might be found to have a small variation if observed with spectrographs of high dispersion over a considerable interval of time.

So far as we know only one star, Boss 6135, has been suspected of a variation in light, and no variation in spectral type has as yet been found by us. Spectroscopic determinations of the absolute magnitudes of these stars indicate that they are all extremely bright with values ranging from −1 to −4, approximately. These values are of much the same order as the absolute magnitudes of the Cepheid variables. A few of them, in fact, such as *δ Canis Majoris*, appear to be brighter than any Cepheid we have so far investigated.

THE MASSES AND ABSOLUTE MAGNITUDES OF VISUAL BINARIES

BY A. VAN MAANEN

For 36 binaries the data now available seem to give a fairly reliable determination of the mass. The results show a correlation between masses and absolute magnitudes which appears to be independent of the spectral type.

NOTE RELATIVE TO THE LOCAL CLUSTER

BY HARLOW SHAPLEY AND MYRTLE L. RICHMOND

An analysis of the stars of type B in the first two volumes of the *Henry Draper Catalog* shows that the local cluster contains few of the fainter stars of this spectral type. Diagrams will be shown illustrating the divergence of the plane of the local cluster from the galactic plane and showing the great extent of the *Perseus* clusters.

ON THE SOURCE OF DISCORDANT VALUES FOR SOLAR ROTATION

BY CHARLES E. ST. JOHN AND L. W. WARE

The differences between the rotation values found by different observers are of the order of the differences found by the same observer upon successive days and even from observations made in immediate sequence. They are greater than the errors of observation and hence have their source either in the solar or terrestrial atmosphere. Investigations now in progress at Mount Wilson Observatory indicate that disturbances in the Sun's reversing layer are occurring with great frequency, and are of such character as to affect observations near the solar limb and of an order of magnitude to produce the discrepancies observed.

WOMAN'S WORK IN ASTRONOMY

BY DOROTHEA KLUMPKE ROBERTS, D. SC.

Her work in the past—her greater work in the future—her duty toward herself and her obligations unto Astronomy for the enlightenment and betterment of mankind.

THE SPECTROSCOPIC ORBIT AND ABSOLUTE DIMENSIONS OF THE ECLIPSING VARIABLE U OPHIUCHI

BY J. S. PLASKETT

By the combination of the orbital elements deduced from photometric observations with radial velocity results, the absolute dimensions, masses and densities of this system have been obtained.

THE FIGURE OF THE 72-INCH MIRROR UNDER CONSTANT AND CHANGING TEMPERATURE CONDITIONS

BY J. S. PLASKETT

Measurements of the zonal aberrations of the mirror by the Hartmann method were made both in the optical shop and under varying observing conditions. The change in form under average conditions both before and after the insulating protection was applied is exhibited graphically.

THE SPECTRA OF THE ORION NEBULA AND NEIGHBORING NEBULOSITIES

BY V. M. SLIPHER

A preliminary note will be given on the spectra of different parts of the *Orion* nebula and of some of the associated or neighboring nebulosities. Slides will be shown of some of the more significant cases.

APPEAL FOR VARIABLE STAR OBSERVERS

BY WILLIAM TYLER OLCOTT

Owing to the fact that at present there are practically no observers of variable stars on the Pacific Coast, the American Association of Variable Star Observers makes a special appeal to observers in this locality with telescopes of three-inch aperture or larger to join the Association and co-operate with it.

The work is of great practical and scientific value and is particularly adapted for the field work of astronomical students in our institutions of learning.

The Association issues a booklet containing instructions for observing and provides the necessary charts. All interested are requested to address the Secretary of the Association, William Tyler Olcott, Norwich, Conn.

AN AUTOMATIC OPTICAL PERIODOGRAPH

BY A. E. DOUGLASS

(Abstract)

This instrument is designed for the rapid preliminary analysis of series of observations such as rainfall, temperature, variable stars, etc., into periodic and some non-periodic elements. Light is passed thru between the plotted curve and some datum line; thence thru a cylindrical lens with vertical axis. In the focal plane the curve-crests appear in light intensity. The vertical lines in the focus pass thru an analyzing plate consisting of narrow, equally spaced parallel transparent lines, tipped at a slight angle from the vertical. Interference fringes are produced which indicate the periods sought. A photograph of the interference or differential pattern so produced is used in detailed study. Condensing lenses are inserted back of the analyzing plate to carry the light thru an integrating cylindrical lens with horizontal axis which reproduces on a vertical slit at the back the summation of horizontal fringes. Back of the slit is a long photographic film mounted on the outside of a drum which rotates as the periodograph moves along its track. The track extends in a direction perpendicular to the plane of the curve in order that the size of the image in the focal plane may change thru a considerable range. The instrument is moved along the track by an electric motor and has automatic focussing and signal devices attached. The image produced on the film is the periodogram. Periods are indicated in it by a beaded or corrugated effect.

This periodograph is especially adapted to the study of cycles and has been used in investigating weather variations and periodic variations in tree growth. It has been tested in the solution of variable star periods. Preliminary forms of parts of it have been described in the *Astrophysical Journal*, October, 1914, and April, 1915.

University of Arizona.

SOME RESULTS OBTAINED BY THE CROCKER ECLIPSE EXPEDITION, JUNE 8, 1918. LANTERN SLIDES.

BY W. W. CAMPBELL AND J. H. MOORE

(Abstract)

From photographs obtained by the Crocker Eclipse Expedition to Goldendale, Washington, with cameras of focal length 4 ft., 15 ft. and 40 ft., we conclude:

1. The general outline form of the corona was more elongated east and west, with reference to its north and south dimension, than the phase of the sun-spot cycle had led us to expect.

2. The short polar streamers of the corona may be in fair agreement with the magnetic lines of force of the Sun, assuming the magnetic axis and the rotation axes of the Sun to be in approximate coincidence, but the other coronal streamers, especially for the inner and middle corona, are not in harmony with such magnetic lines. The forms of the inner coronal streamers seem to be controlled from local centers occupied by solar prominences. Nearly all of the larger prominences and some of the smaller ones are enclosed by hooded coronal forms, which extend in some cases at least ten or fifteen minutes of arc from the Sun's edge. There can be no doubt that the hooded coronal structure is intimately related to the prominences; the forces responsible for one set of phenomena appear to be responsible for both.

3. Comparison of the coronal photographs with the photographs of the photosphere, the prominences, the faculae, and the spots obtained at the Mount Wilson Observatory on June 8th and on a few days immediately preceding and following that date, has shown no apparent relationship between the hooded coronal forms and the prominences on the one hand, and the sun-spots and faculae on the other hand.

4. A comparison of the 40-foot photographs of the inner corona with similar photographs kindly supplied us by the Lowell Observatory, has shown that changes in the details of coronal structure occurred while the Moon's shadow was travelling from Washington to Kansas, but we have not been able to say that motion away from or toward the Sun has occurred.

The distribution of coronium around the Sun seems not to have intimate relationship with the distribution of the prominences and spots.

The wave-length of the green coronium line was determined to be 5303.0A.

A spectrogram of the corona recorded no absorption lines. The well known bright lines of the corona were observed and likewise a few bright lines not previously recorded.

THE EINSTEIN EFFECT; ECLIPSE OF JUNE 8, 1918

BY H. D. CURTIS

The results of measures on plates taken with the Vulcan cameras at Goldendale, Washington, at the eclipse of June 8, 1918.

SUGGESTED PROCEDURE FOR STANDARDIZING RADIAL VELOCITY RESULTS

BY W. W. CAMPBELL

(Abstract)

The accidental errors in radial velocity observations are relatively small, but the question of eliminating or reducing the size of systematic errors is still with us for solution. The subject should have our careful consideration, in order that radial velocities of stars determined at different observatories and with different degrees of dispersion may be combined into one harmonious system.

The so-called "Zero-Velocity" reduction table accomplishes this for Class G stars, because the actual radial velocity of the Sun, a Class G star, may be computed from the known elements of the Earth's orbit.

Reduction tables for spectra of classes F, A, B, Oe5, in so far as they consist of isolated absorption lines, depend upon the assumption that the wave-lengths of these lines, lines embracing a great variety of widths, are identical with the corresponding narrow radiation lines as observed in the laboratory. This assumption may not represent the truth, and there are some indications that it does not.

The class G reduction table serves fairly well for stars of classes K1-3, but it is more and more unsatisfactory as we proceed thru the classes K5, Ma-d, and N. The relative intensities of lines in the solar spectrum are not preserved in those of classes K5 to N. Results based upon class G tables are probably appreciably in error, and this error is liable to be especially serious when low dispersions are employed.

To eliminate the uncertainty in part, and perhaps as far as we are now able, it is recommended that two or three of the brightest stars in each of the main spectral classes K1, K5, Mb and N be observed with the highest available and practicable dispersions, preferably on medium-speed plates, in order to eliminate as many blended combinations of lines as possible. Certainly for classes K, K5, and Mb the spectrographs should have dispersion higher than the existing three-prism instruments afford, if fortunately such more powerful instruments may be available in any radial velocity observatory. On these spectrograms the lines apparently single and identical with lines in Rowland's solar spectrum should be selected for measurement, and the equivalent radial velocities be deduced on the basis of Rowland's wave-lengths (for the present). Such observations should be repeated from time to time to insure that the stellar velocities are apparently constant, and the mean values of such observations should be adopted as the most probable radial velocities of these stars.

All observers of classes K, M, and N stars, no matter what dispersive powers their instruments may have, should secure four or more thoroly satisfactory observations of some of the standard stars in each spectral class, and either make their reduction tables for each class reproduce the high dispersion standard velocities, or determine the discrepancy and apply it to each observed velocity of the stars in that class.

If measurements are to be made by the Hartmann spectrocomparator, using with each spectral class a reference plate of the same class, this plate should be compared with plates of the high-dispersion standard stars of its class, and the radial value of the reference plate be arbitrarily fixed to reproduce exactly the adopted velocities of the standard stars.

RADIAL VELOCITIES OF STARS OF SECCHI'S FOURTH TYPE

BY J. H. MOORE

Our present knowledge of the radial velocities of fourth type, or class N, stars is very limited. Only a comparatively small number of these stars are of sufficient brightness to permit of obtaining spectrograms of them with spectrographs of sufficient dispersion for reliable radial velocity determinations. Measures previously made for a few members of this class appear to be affected by uncertainties in the adopted wave-lengths, incident to the peculiar spectra given by these stars, and the low-dispersion necessarily employed.

In the present investigation an attempt has been made to secure observations of all class N stars whose spectra can be successfully photographed, with one-prism dispersion, in the region 4400-4800A. These spectrograms have been measured on the Hartmann-spectrocomparator, using as standard comparison plates spectrograms of two class N stars whose radial velocities were accurately determined with three-prism dispersion. By this procedure, it is believed that the serious effects of uncertainties of wave-length have been reduced to a minimum.

The preliminary results of the application of this method to a number of class N stars are given.

A Periodic Variation in the Observed Latitude at Mount Hamilton

BY R. H. TUCKER

The observations of latitude for the years 1917 and 1918 have a periodic term of the form $-0''.3 \cos t$, where t is reckoned from the beginning of the year. The form of this periodic term is similar to that of one of the terms of the variation of latitude due to the motion of the pole, but the computed corrections for this variation have been applied to the original observed values of latitude, which include a more pronounced variation than that hitherto accepted.

The declinations of the fundamental stars have been examined for periodic terms depending upon right ascension. For the zone from +40° to +65° declination the A. G. fundamental system differs from that of the *American Ephemeris* by $-0''.14$ for the mean of 72 stars, the average residual being $\pm 0''.17$ per star. There is no distinct periodic variation in the differences.

The revised A. G. system now in use differs from the original A. G. system by $+0''.17$ for the mean of 150 stars in this zone, the average differences being $\pm 0''.34$ per star.

The revised A. G. system differs from that of the *Preliminary General Catalog* of Lewis Boss by $+0''.07$ for the mean of 150 stars in this zone, the average difference being $\pm 0''.10$. There is a periodic term of the form $-0''.054 \cos \alpha$. The old A. G. system compared with Boss has periodic terms: $+0''.16 \sin \alpha - 0''.06 \cos \alpha$. These periodic terms derived from comparison of fundamental systems of declinations are not large enough to account for the observed variation in latitude. Nearly 1200 observations of latitude have been included in this discussion, obtained in a period of fourteen months. The observations of latitude from the circumpolar stars in the period indicate a correction of $+0''.2$ to the mean of the A. G. declinations in the zone $+40°$ to $+65°$.

The variation in the observed latitudes is too large to be ascribed to any seasonal variation in the refraction corrections, at the moderate zenith distances of this zone, and probably it can only be explained by some local conditions of a transitory character.

May 13, 1919.

PERIODIC VARIATION IN THE POSITION OF THE MIRE AT MOUNT HAMILTON

BY R. H. TUCKER

All the observations since the year 1893 unite in giving an annual variation of approximately $0''.8 \sin t$, where t is reckoned from the beginning of the year.

Observations of a fundamental character indicated the existence of a diurnal term also, in the periodic variations.

For ten years, 1893 to 1903, there was no sensible change in the mean position. From 1903 to 1912 there was a progressive secular change of $-0''.6$ per year. Since 1912 there has been no sensible change in the mean position.

Periodic changes in position are to be explained probably by the effects of temperature upon the south slope of the mountain, near the edge of which the pier for the mire is located.

May 13, 1919.

A FEW RESULTS OF THE RECENTLY COMPLETED PROGRAM OF RADIAL VELOCITY MEASUREMENTS OF THE BRIGHT-LINE NEBULAE

BY W. W. CAMPBELL AND J. H. MOORE

(Abstract)

The program for the determination of the spectrographic velocities of the bright-line nebulae, from observations secured at Mount Hamilton and at our branch observatory at Santiago, Chile, was completed last year for all known objects of this class bright enough to be observed with exposure times of practicable length. A few of the statistical results of this investigation are as follows:

1. The radial velocities of 125 bright-line nebulae have been determined.

2. In addition to the 18 nebulae in the Magellanic Clouds, there are six planetary nebulae whose observed radial velocities exceed ±115 km/sec. It is interesting to note that these six are located in a very small area of the sky (R. A. = 15.1 to 19.2 hours; Decl. = $-9°$ to $-30°$).

3. The remaining 101 observed nebulae yield a speed of -23.6 km/sec. for the motion of the solar system with reference to them as a system, assuming the apex of motion to be at R. A. = 270°, Decl. = $+30°$. The system of 101 nebulae as a whole is therefore substantially at rest with reference to our stellar system.

4. The average radial velocity of the five extended irregular nebulae with reference to the stellar system is ±11 km/sec. Excluding the 18 Magellanic nebulae, the average radial velocity of the 102 planetary nebulae outside of the Magellanic Clouds is ±37 km/sec. If we also exclude the other six nebulae (planetaries) which have very high velocities, the average velocity of 31 planetaries whose diameters are less than 5 seconds of arc, and which have been called "stellar" nebulae on that account, is ±28 km/sec., and that of the other 65 planetaries (whose diameters are greater than 5 seconds) ±31 km/sec. The stellar nebulae are found exclusively in one quadrant of the Milky Way.

5. The evidence for a Kapteyn preferential motion of the bright-line nebulae is present if we include the group of six high-velocity planetaries, and is essentially absent if we exclude the six.

A STUDY OF CERTAIN NEBULAE FOR EVIDENCES OF POLARIZATION EFFECTS

BY W. F. MEYER

(Abstract)

The spiral nebulae and certain types of extended irregular nebulae present conditions which have led some astronomers to suggest that these objects may be shining by reflected light. The original source of illumination, under this hypothesis, is assumed to be in the nuclei of the spirals and in the stars within or near the extended nebulae, and the nebular materials polarize by reflection and diffusion the rays of light falling upon them. Some of the conditions which suggest the reflection hypothesis are:

1. Nearly all of the spirals have spectra closely resembling the

spectra of yellow stars, and a few of the extended nebulae show the same types of spectra as the stars apparently involved in them.

2. A few nebulae which involve stars known to be variable have spectra of the same types as the stars, and these nebulae also vary in brightness and apparent form. It is postulated that these nebulae receive their light in whole or in large measure from the variable stars within or relatively near them.

3. Those spiral nebulae which are seen edgewise or nearly so, show each a dark lane superimposed upon its image and parallel to the direction of its greatest dimension. This phenomenon, some have suggested, may possibly be explained by the reflection hypothesis. The parts or particles of such a nebula which lie nearest to us should, on this hypothesis, be bright on the faces turned away from us and toward the radiating nucleus, and relatively dark on the faces turned toward us.

A study of representative spiral and variable nebulae for evidences of polarized light is very desirable, in order to test the reflection hypothesis of the origin of their light. For this purpose a polarigraph was designed for use in connection with the Crossley reflecting telescope. Nebulae of both types were photographed in duplicate by means of this optical combination; each nebula once with the principal plane of the analyzer coinciding with a given diameter of the object, and again with the principal plane at right angles to this position. The pairs of images were examined with the Hartmann microphotometer to detect differences of intensities along the two diameters of the nebular images.

To test the sensitiveness of the polarigraph, extensive laboratory experiments were made with different percentages of plane-polarized light. As a further test, "artificial" nebulae were illuminated with polarized light, so as to reproduce as nearly as practicable the appearance of the objects studied. As a result of the laboratory experiments, it was concluded that if as much as ten per cent of the light in each image were plane-polarized, this property would not escape detection.

At least twelve nebulae were satisfactorily photographed and their images critically examined. In no instance was the evidence of polarization sufficient even to suspect its presence. We conclude that if some of the light coming from the nebulae under investigation is modified by reflection or scattering by small particles, the proportion of light thus polarized is less than ten per cent of the light received from these objects.

NOTES FROM PACIFIC COAST OBSERVATORIES

The Masses of Visual Binary Stars

In *Contributions from the Mount Wilson Solar Observatory* No. 142, Adams and Joy publish a list of parallaxes of 500 stars determined by Adams's spectroscopic method. Comparing their list with the list of orbits of visual binary stars printed in my book, *The Binary Stars*, I find 28 stars common to the two. As every addition to our knowledge of the masses of the binary systems is of the highest interest, I have examined these 28 systems to determine their value in this connection.

It is well known that when the distance, or parallax of a binary star has been determined as well as the elements of its orbit, the mass of the system, in terms of the Sun's mass, can be computed from Kepler's harmonic law put in the form,

$$(m + m_1) = \frac{a^3}{\pi^3 P^2},$$

in which π is the parallax of the system, P the period, a the semi-axis major of the orbit and the units of mass, length and time are, respectively, the Sun's mass, the astronomical unit and the year. Table IX (page 209) of my book gives the masses of 14 visual binaries computed by means of this formula. Two of these stars are *Sirius* and *Alpha Centauri;* the remaining 12 are also in the list of 28 mentioned above. According to the data of my table the masses of these 12 pairs range from 0.45⊙[*] (Krueger 60) to 3.3⊙ (ε *Hydrae*), and the mean mass of a system is 1.61⊙. Using the parallaxes given by Adams and Joy for these 12 stars, I find the range to be from 0.21⊙ (ε *Hydrae*) to 7.21 (ζ *Herculis*), and the mean mass of a system to be 1.67⊙. While there are considerable discordances for individual systems, the agreement of the means is so close that we may regard the new parallaxes, in the average, as accurate for mass determinations as those derived by trigonometric methods. I have therefore used them to compute the masses of 7 additional systems for which the elements are known with sufficient exactness. The results are as follows:

Star	Magnitudes	Spectrum	Period (Years)	a	π	$(m + m_1)$
β 395	6.4–6.5	K0	25.0	0.66	+0″.066	1.60 ⊙
β 883	7.9–7.9	F5	16.61	0.19	0 .033	0.69
Σ 3121	7.6–7.9	K0	34.0	0.67	0 .083	0.46
γ Virg.	3.6–3.7	F	182.3	3.74	0 .078	3.24
β Delph.	4.0–5.0	F5	26.79	0.48	0 .038	2.81
τ Cygni	3.8–8.0	F0	47.0	0.91	0 .042	4.60
κ Pegasi	5.0–5.1	F5	11.35	0.29	0 .066	0.66
Mean mass, 7 systems						2.01 ⊙

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[*] Symbol for Sun.

Taking the masses of the seven stars in this table, the masses of the 12 systems mentioned above as deduced from the spectroscopic parallaxes and the masses of *Sirius* (3.3⊙) and of *Alpha Centauri* (2.0⊙), which are the best determined stellar mass values we possess, we have a total of 21 systems, with masses ranging from 0.21⊙ to 7.21⊙, the mean value being 1.88⊙. Some of the individual mass values must still be regarded as quite uncertain, but the mean result may be taken as strong confirmatory evidence that, in the average, the visual binary systems, at least the short-period systems relatively near to us, are about twice as massive as our Sun.

The number of systems is hardly large enough to permit safe deductions as to possible correlations between mass and spectral class or between mass and absolute magnitude; but it is of interest to note that the five stars of classes K and M are, on the average, only half as massive as the 16 stars of classes A to G, and are, on the average, nearly four magnitudes (absolute) fainter.

R. G. AITKEN.

April, 1919.

AN INTERESTING VISUAL BINARY SYSTEM

In 1892, Hough found a 13th magnitude companion to the 6.7 magnitude star B. D. +26°, 1865 (R. A. $8^h49^m00^s$; Decl. +26° 36′; spectrum G0); in 1910, I discovered the bright star itself to be a close unequal pair (A 2131), and my measures of Hough's companion (Ho 357) showed a very decided increase in the distance with slow change in the angle in the interval of eighteen years.

I have just repeated the measures of these stars and give here my two sets of measures together with those of Hough for the wide pair.

Ho 357

1892.29	8°.2	31″.06	2n	18½-inch	Hough
1910.13	4 .2	38 .79	2n	36-inch	Aitken
1919.19	3 .2	42 .76	2n	36-inch	Aitken

A 2131 = Ho 357 AB

1910.15	254°.6	0″.32	3n	36-inch	Aitken
1918.00	298 .8	0 .30	1n	36-inch	Aitken
1919.19	299 .4	0 .32	2n	36-inch	Aitken

The three measures of Hough's companion fall quite precisely upon a line in position angle 169°.5 and indicate a proper motion of the bright star in that direction amounting to 0″.445 per year.

In *Cincinnati Publications* No. 18, the proper motion of this star is given as 0″.44 in 173°.1, and the agreement of the two results is satisfactory proof of the independence of the small star.

The measures of the close pair point to rapid orbital motion and a relatively short revolution period. Since Hough did not note the pair in 1892 when he discovered the distant companion it is probable that the angular distance then was smaller than it is now. The rapid orbital motion as well as the large proper motion makes it probable that the system is among the nearest stars and suggests that its parallax may be measurable by direct methods.

ROBERT G. AITKEN.

March, 1919.

THE DOMINION ASTROPHYSICAL OBSERVATORY

From an article in the *Daily Colonist,* Victoria, B. C., we learn that Mr. W. E. Harper, M. A., "has assumed his duties as astronomer and chief assistant to Dr. J. S. Plaskett," at the Dominion Astrophysical Observatory. The article also states that Captain H. H. Plaskett has received an appointment as observer for the same observatory. Captain Plaskett is at present in England taking a postgraduate course at the Imperial College of Science, London. He has been overseas since April, 1917, having enlisted at Toronto in April, 1916, while attending the university. To quote further, "The activity of Dr. J. S. Plaskett and Dr. Young in the intervening time [since April 28, 1918] is evidenced by the fact that up to date thay have obtained no less than 1850 spectra. . . ."

THE NEW CHABOT OBSERVATORY

The Oakland City Board of Education has appropriated the money needed to complete the building for the new Chabot Observatory at Leona Heights. The dome for the new 20-inch telescope and a shelter for the transit instrument and the clocks were completed, and the instruments installed, early in 1916. The present appropriation will provide a dome for the 8-inch equatorial now at the old observatory, and a building, for offices, library and reception room, connecting the two domes. This will give the Oakland School Department the finest astronomical observatory possessed by any city in this country. Mr. Charles Burckhalter, the director of the observatory, in addition to his personal researches in astronomy, has led thousands of young people to take an interest in the stars. Every school child in the city has the opportunity to visit the observatory, look thru the telescope, and learn from Mr. Burckhalter something of the Moon, the Sun, the planets and the stars. If work of this character were carried out in all our schools we should not have *school teachers* exclaim at the sight of *Jupiter* thru the telescope, as one did at the Lick Observatory, "Why! Is that a star? I thought all stars had five points!"

R. G. A.

HONORARY ELECTIONS TO ACADEMIES

Professor George E. Hale, Director of the Mount Wilson Observatory, has been elected a Foreign Associate in the Paris Academy of Sciences, in succession to Dr. A. von Bayer.

Dr. H. D. Curtis, Astronomer in the Lick Observatory, and Dr. F. H. Seares, astronomer in the Mount Wilson Observatory, have been elected to membership in the National Academy of Sciences.

Dr. R. G. Aitken has been elected to membership in the American Philosophical Society.

W. W. C.

APPOINTMENTS IN THE LICK OBSERVATORY

Mr. Charles Morse Huffer has been appointed Assistant Astronomer for service at our branch observatory on Cerro San Cristobal, Santiago, Chile.

Mr. C. D. Shane, Mr. H. M. Jeffers, Miss Edith E. Cummings, and Miss Priscilla Fairfield have been appointed University Fellows in the Lick Observatory for the academic year 1919-20.

Dr. Robert J. Trumpler, at present Assistant in the Allegheny Observatory, has been appointed to the Martin Kellogg Fellowship in the Lick Observatory for the next academic year.

W. W. C.

GENERAL NOTES

The Adolfo Stahl Lectures in Astronomy.—Several announcements of the publication in book form of the two series of Adolfo Stahl Lectures in Astronomy have already been made in these PUBLICATIONS. The volume is now ready for distributions and copies may be obtained for $2.75 each, postpaid, on application to the Secretary of the Society, Mr. D. S. Richardson, 128 Lick Building, 35 Montgomery street, San Francisco, Calif.

The contents of the book are as follows:

The Solar System, by W. W. Campbell.

What We Know about Comets, by W. W. Campbell.

A Total Eclipse of the Sun, by R. G. Aitken.

The Moon, by R. G. Aitken.

The Nebulae, by H. D. Curtis.

Astronomical Discovery, by H. D. Curtis.

The Important Epochs in the Development of Astronomy, by R. T. Crawford.

Our Nearest Star, The Sun, by C. E. St. John.

News from the Stars, by R. G. Aitken.

Recent Progress in the Study of the Motions of Bodies in the Solar System, by A. O. Leuschner.

The Brightness of the Stars, Their Distribution, Colors and Motions, by F. H. Seares.

The 100-Inch Reflecting Telescope, Mount Wilson.

The last paper has been compiled by the editor, with the assistance of members of the Staff of the Mount Wilson Observatory, to take the place of the lecture on this subject delivered by Professor G. W. Ritchey which he, unfortunately, was unable to put into written form because of the pressure of work for the government in connection with the war.

The book is substantially bound in full art-vellum and is illustrated by fifty-six full-page half-tone plates and twenty-four figures in the text. These illustrations include photographs and drawings of solar phenomena, the Moon, the planets, the comets, the nebulae, star-clusters, and star-clouds of the Milky Way; portraits of great astronomers and photographs of astronomical instruments, particularly the great telescopes on the Pacific Slope.

Each lecture has been revised by its author and the statements in it represent our knowledge of the subject treated at the close of the year 1918. The book will therefore serve as an introduction to many phases of modern astronomy.

The International Astronomical Union.—In accordance with decisions made by leading representatives of the sciences at meetings held in London in October, 1918, and in Paris in November, 1918, there will be a meeting of astronomers of the allied countries in Brussels, Belgium, on July 16, 1919, to organize an International Astronomical Union. The representatives from the different countries have been chosen by the leading academies of sciences and astronomical societies. An American delegation is in process of selection by the National Academy of Sciences, the National Research Council, and the American Astronomical Society. Director W. W. Campbell of the Lick Observatory has been appointed chairman, and Professor Joel Stebbins of the University of Illinois, secretary, of the delegation. It is hoped that the complete personnel of the delegation may soon be announced. The American delegation will have five votes in the conference, but the provisional rules have placed no limit upon the number of delegates who may take part in the deliberations. W. W. C.

The Cawthron Trust and Solar Observatory.—Dr. C. E. Adams, Government Astronomer, Wellington, New Zealand, sends a clipping from the New Zealand *Dominion* for March 17, 1919, on the Cawthron Trust and its aims. It appears from a statement by Mr. T. A. H. Field, one of the Trustees, to a Parliamentary Committee, that the Trust now holds a cash fund of £213,000 in addition to lands valued at £5570. The trustees plan to keep the capital fund intact at £200,000 and to pay for buildings, equipment, etc., from the income.

Among their plans are two which will be of interest to our readers. First, the founding of seven scholarships and fellowships with annual stipends ranging from £105 to £250, open to all New Zealand and designed to stimulate scientific training and education in that dominion. Second, the establishment in Nelson, New Zealand, of a Solar Observatory. "The late Mr. Cawthron was very much interested in the establishment of a solar observatory in Nelson, whose climate is particularly suited for this purpose. . . The land was purchased for the observatory before the late Mr. Cawthron's death."

PUBLICATIONS
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ON THE SOURCES OF STELLAR ENERGY[1]

BY HENRY NORRIS RUSSELL

Dr. Shapley's stimulating note[2] (which he kindly communicated to the writer in advance of its publication), suggests the communication of some results of a study of the same topic which is still in progress.

1. The strongest evidence against the hypothesis that the rate of radiation from a hot body to space is considerably less than it would be to a material enclosure at the absolute zero is found in the present state of the Earth. According to Abbot (*Proc. Nat. Acad.*, 4, 104, 1918), the energy which the Earth actually receives from the Sun, after allowance for reflection back into space, amounts, on the average, to 0.29 calories per square centimeter per minute over the whole surface. The mean temperature of the surface is 287° Abs, to which corresponds a black-body radiation of 0.55 $\mathrm{cal/cm^2/min}$. The temperature of the effective radiating surface of the Earth is considerably lower than this, since much of the outgoing radiation comes from the upper atmosphere, and it is probable that neither the actual surface nor the atmosphere is a perfect radiator.

It follows that the ratio of the rate at which the Earth actually radiates heat to space to the rate at which it would radiate to a surrounding material enclosure at the absolute zero is much greater than 0.29/0.55—that is, much greater than 0.53, and there is no evidence that it is less than unity. But the ratio which would be required to reconcile the probable ages of the Sun and stars with a purely gravitational supply of energy is of the order of magnitude of 0.001. Unless, then, we make the extremely unsatisfactory assumption that the law of radiation from a hot body to *empty space* is entirely different for the long waves emitted by the Earth and the short waves emitted by the Sun, we appear to be shut up to the conclusion that the Sun and stars have actually radiated during their active life, many times more energy than would be liberated by gravitational compression during their contraction from infinity.

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[1] Presented at the Pasadena meeting of the *Ast. Soc. Pac.*, June 19, 1919.

[2] *Publications of the Ast. Soc. Pac.*, June, 1919.

2. It must therefore be assumed that there exists within the stars some unknown store of energy of enormous magnitude, which is made available to supply the heat lost by radiation. Tho the nature of the process by which this energy is transformed is unknown, we do know that it must satisfy certain conditions:

(*a*) It must generate large quantities of heat per unit mass in the interior of the stars, and very little or none under laboratory conditions, or in the interior of the Earth.

(*b*) It must not be liable to accelerate its own rate so as to end in an explosive catastrophe, for the stars in general appear to be very stable, and the phenomena of Novae are apparently superficial rather than deep-seated.

(*c*) It must in some way be regulated so as to supply heat to each star at almost exactly the rate at which the star radiates heat to space, for the rate of energy transformation in the processes of stellar evolution is evidently exceedingly slow.

(*d*) It must ultimately die down as time goes on, making it possible for a star to proceed to the dwarf stages in which its radiation is small.

(*e*) A sufficient amount of energy must still be available in these later stages to permit them to be of very long duration, for the large majority of the stars per unit of volume are dwarfs.

3. Some of these conditions are easily met. For example, (*a*) leads to the assumption that the process operates at a perceptible rate only under extreme conditions of temperature or pressure, such as prevail in the interior of the stars. Condition (*d*) is sufficiently met by assuming that the energy is derived from some finite store which is gradually exhausted, and that the rate of transformation falls off as the remaining supply decreases. This hypothesis leads naturally to the further consequence that complete exhaustion will be approached asymptotically, and hence satisfies condition (*e*).

But conditions (*b*) and (*c*) present serious difficulties. If the hypothetical process is to satisfy condition (*a*), the rate at which it takes place must have a positive temperature coefficient. But if this is true, why does not the process, when once started, steadily raise the temperature, and so accelerate its own rate, until it culminates in an explosion of tremendous proportions? And what can be the mechanism which not only prevents this, but automatically adjusts the rate of transformation of this enormous store of internal energy to exactly the rate required to meet the loss by radiation? To add to the complexity there is good evidence that among the giant stars the rate of radiation (Eddington's bolometric magnitude) varies very little with the density among stars of the same mass, but that the total radiation *per unit of mass* is considerably greater for the more massive stars.

4. It does not appear to have been noticed that a simple explanation of these difficulties may be found in the fact that a sphere of perfect gas, in equilibrium under its own gravitation, has as a whole *a negative specific heat.* If such a mass passes thru a series of "homologous" configurations, its temperature rises, according to Lane's Law, as it contracts, while at the same time its total store of energy diminishes. If heat should be supplied to the interior of such a star, it would expand and its temperature would fall—the amount of energy expended in expanding against gravity being greater than that supplied in the form of heat. This apparently paradoxical behavior is closely analogous to certain other cases where other forms of energy are transformed into gravitational potential energy, for example, to the acceleration of a comet's mean motion by a resisting medium. Tho the simple model of the sphere of perfect gas passing thru a series of homologous states may not exactly represent the facts, it is evident that the possession of a negative effective specific heat is an essential property on any theory of a giant star which contracts and rises in temperature while losing heat by radiation. Without this property, such a star would be incapable of supplying its radiation losses by means of gravitational contraction.

To this must be added the assumption that the rate at which a star can get rid of heat of deep-seated origin by radiation depends upon its mass, its density, and the opacity of the material of which it is composed. This conclusion has been reached theoretically by Eddington, on the basis of certain simplifying assumptions, and by Jeans, on another set of postulates. Both agree that the total radiation of a giant star should be almost independent of its density. For the present purpose, the exact validity of the assumptions made by either investigator is unimportant so long as it is assumed that their conclusions correctly represent the general course of the actual phenomena. This assumption is strongly supported by the observed characteristics of the giant stars, which also indicate that the coefficient of opacity is surprisingly similar in different stars.

5. Suppose now that there is a large mass of gas of very low density, and in equilibrium under its own gravitation. At first its temperature will be relatively low thruout, and it will have to depend on gravitational contraction to supply the energy lost by radiation. It will contract at a relatively rapid rate, and its temperature will rise. As its central regions reach the critical temperature at which the evolution of heat by the "unknown process" postulated above becomes sensible, this supply will begin to supplement the heat due to contraction. The rate of radiation, being determined almost entirely by the mass and opacity, will remain nearly constant, but, as the temperature of the interior rises, more and more of this outgo will be supplied by the "unknown process" and the rate of contraction will become very slow, so that the further rise of central temperature will be checked. Should this temperature rise too high so that heat was produced faster than it could be radiated away, the star would expand, its temperature would diminish, and the supply of heat would be partially cut off; but if the central temperature fell too low, too little heat would be generated, the star would contract, its temperature would rise, and the internal supply of heat would be augmented. It is clear that an approximately steady state will be reached in which just enough of the material in the interior of the star is just hot enough to supply, by the "unknown process," the amount of heat needed to support the radiation. The law of distribution of temperature, density, etc., thruout the mass will differ somewhat in this state from that which prevailed when the energy was derived from contraction, but the new state will be stable, not only with respect to changes in the distribution of matter, but also with respect to variations in temperature and in the rate of generation of heat.

The duration of this stable state will be conditioned by the supply of energy available from the "unknown" source, and may be very great. As this supply, however, becomes gradually exhausted, more and more of the interior of the star will have to be heated above the critical temperature in order to keep up the supply of heat from the impoverished material, and the average temperature of the interior will rise. These changes will be accompanied by a contraction of the star, and an increase of its effective surface temperature, so that it will pass slowly along the series of giant stars. The series of states thru which it will pass will not be "homologous" since the fraction of the mass which is involved in the transformation of the "unknown" energy steadily increases; but, qualitatively, its evolutionary progress will be similar to that of a mass dependent upon contraction for its energy, reaching a maximum effective temperature at a density considerably less than that of the Sun, and then following the series of dwarf stars. The rate at which these changes take place will, however, be very much slower, and the relative intervals of time required to pass thru corresponding stages may be different. It is easy to see that, in comparison with a star which derives its energy from contraction, the giant stages will occupy a greater proportional interval (since most of the great store of energy is transformed during these stages). The dwarf stages, however, will still occupy more time than the giant stages, since the rate of transformation of energy is so much smaller.

6. The hypothesis thus sketched in outline appears to meet the outstanding difficulties (*b*) and (*c*), and to afford a reasonable solution of the problem of the source of stellar energy. Several remarks may be made regarding it.

First, the only assumptions that have been made regarding the "unknown source" of energy are: that the energy supply is finite, tho great, and that the rate of its transformation into heat depends upon the amount still available for transformation, and increases steadily with the temperature of the medium in which the transformation takes place. These properties are so general that they convey little information regarding the nature of the process; but it is obvious that almost any of the sources which have so far been suggested—such as atomic disintegration or mutual neutralization of positive and negative electric charges—would meet the conditions. The present argument has, however, been purposely kept clear from discussion of the details of any such hypothesis.

Second, this hypothesis suggests for the internal constitution of a giant star: (1) a nucleus, for which the temperature is above the critical limit where the liberation of energy by the "unknown process" becomes sensible and within which practically all the energy required to maintain the surface radiation is liberated, and (2) an outer shell of lower temperature, in which very little heat is produced, but which is in a state of radiative equilibrium and conditions the rate at which the internal energy can reach the surface and escape into space. The problem of determining the law of distribution of density or temperature within such a body, tho perhaps difficult, is doubtless capable of solution by known methods.

Third, it is of much interest to note that the hypothesis outlined above presents a direct explanation for two astrophysical facts that have so far been hard to account for. The first of these is the remarkable infrequency of occurrence of very red giant stars. Stars with a color index exceeding two magnitudes are practically unknown (except in the branch series which includes the spectral classes R and N and apparently represents exceptional conditions involving only a small proportion of all the stars). On the contraction hypothesis, the apparent absence of stars in a state antecedent to the familiar and fairly abundant Class M is very puzzling; but on the new hypothesis it is only necessary to assume that the interior of a giant star does not reach the temperature at which the supply of heat from the "unknown source" is important until its effective surface temperature has reached the value characteristic of Class M. Stars in earlier states of evolution would then run thru their course so rapidly that there would be very few of them in a given region of space at any one time, and their rarity is thus accounted for. The second is the maintenance of variability of the Cepheid type. It now appears probable that the cause of this variability is some form of pulsation, involving a bodily contraction and expansion of the star, with corresponding changes in temperature. Eddington has shown that the "leakage" of heat from the hotter to the colder regions of the star's interior would tend to damp out such pulsations within a few thousand years at most. But the process suggested above supplies heat to the interior at the greatest rate just when and where it is hottest, and would thus tend to make good the "leakage." It seems probable, therefore, that in such a process may be found the driving force which maintains Cepheid variation. On this hypothesis the liberation of heat would take place mainly when the star was smallest and hottest (internally, at least). This supply of heat in periodic "impulses" may have some connection with the asymmetry of the light and velocity curves.

The singular relation which connects the period and the absolute magnitude of Cepheids may perhaps also find an explanation in this hypothesis. It is pretty clear, from astronomical evidence, that Cepheid variation is something which occurs at a definite stage in the evolution of a star, and that the density at which it is developed varies with the mass of the star, and is lower the greater the mass. Let it now be assumed that the occurrence of Cepheid variation is dependent upon some relation between the size of the heat-producing nucleus and the remainder of the star. Stars of large mass will have a higher central temperature for the same density; the formation of such a nucleus will therefore begin in them at a lower density than in stars of smaller mass and, at the same density, the nucleus will be proportionally larger. The assumed relative size of the nucleus will therefore be reached at a density which is definite for any assigned mass, but is lower the greater the mass.

Princeton University Observatory,
June 9, 1919.

ON THE SPECTRA OF THE ORION NEBULOSITIES[1]

BY V. M. SLIPHER

In the course of the nebular investigations at the Lowell Observatory, spectrograms have been secured of different parts of the Great Orion Nebula and of the neighboring nebulosities; and it will perhaps be of interest at this time to give briefly some of the results. These could be given more advantageously pictorially with the use of a lantern, but owing to the difficulty of reproducing without misleading imperfections such delicate plates, it will be necessary here to resort to descriptions of some of the more interesting and typical spectra.

At this point it may be helpful for the reader to refer to page 496 of Miss Clerke's *Problems in Astrophysics* where is reproduced a photograph of the constellation of *Orion* made by Prof. W. H. Pickering, in 1890, from Mount Wilson. This plate revealed the great encircling cloud of nebulosity in *Orion*, and thus has the distinction of furnishing the first of that already long list of valuable astronomical discoveries made from the vantage point of Mount Wilson.

On this plate it will be seen that the great encircling nebulous band begins a little way southeast of γ *Orionis* and swings to the eastward and southward, passing at a distance the belt and sword-handle of *Orion;* then to the westward passing near κ and curving inside *Rigel* to the northward to η or possibly to the belt. All the nebulosities to be discussed spectrally in this paper lie within the confines of this enveloping cloud: the nebula N. G. C. 2068 is in the dark spot northeast of ζ, being the most distant from the Great Orion Nebula about θ.

With the nebular spectrograph attached to the 24-inch refractor, a twenty-hour exposure was made for the spectrum of the brighter part of the Great Nebula. For this plate the slit of the spectrograph was N-S near the Trapezium. The negative records many emission lines between the well-known brilliant nebular lines λ 3727 and λ 5007, and a weak continuous spectrum. One recognizes no dark lines crossing the continuous spectrum, but this is not surprising, for experience with other nebulae—as that of the *Pleiades*, that about ρ *Ophiuchi*, etc.—leads one to expect the continuous spectrum to match that of the Orion stars, in which case the dark lines would fail to show, for they would be covered over by the bright nebular lines of hydrogen and helium. While it is not possible to decide that the continuous spectrum is of the Orion type, it is nevertheless clear that it is not of the solar type, since none of the characteristic solar dark lines are present. In addition to the continuous spectrum and the better known bright lines of the nebula, many faint lines are present, some of which are doubtless new. These are perhaps for the most part fainter members of the known series; an example of such is furnished by the helium line between Hβ and N_2.

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[1] Read at the Pasadena meeting of the *Ast. Soc. Pac.*, June 19-20, 1919.

Another long exposure spectrogram was made with the same instrument, with the slit placed E-W near the Trapezium. This presents a generally similar spectrum. The definition is especially good far into the violet and many fine emission lines show there, chiefly of the hydrogen series, several of them on the more refrangible side of λ 3727 in the ultra violet. On both these spectrograms the line λ 3727 is clearly resolved into its two known components. Fully forty bright lines are to be counted on this plate. It is of interest to note that N_1 and N_2 are much weaker relative to Hβ on the east edge of the spectrum than on the west. The continuous spectrum is fainter on this plate, due mainly to a narrower slit than was used for the preceding plate, and like that plate this one shows no absorption lines. These plates show a disposition in the lines N_1 and N_2 to fade relative to hydrogen Hβ toward the outer parts of the main nebula.

A spectrogram was also made of the nebular cloud about the bright star Bond 734 just north of the "fish-mouth," cataloged as N. G. C. 1982. The location of the slit was E-W over the brightest portion of the nebula. The plate of the spectrum of this nebula reveals a great difference in the relative intensity of the nebulium and hydrogen lines, implying a wide difference in the distribution of these two substances. There is also a great difference in the intensity of the line 3727 and the lines N_1 and N_2, suggesting that the so-called "nebulium" giving the latter lines is not responsible for the ultra-violet line. Thus we seem to have to do with "nebulium" I and "nebulium" II. The Trifid Nebula, for example, furnishes another example of this.

The helium line λ 4472 appears as a weak emission on the west edge of the nebula, and thus resembles "nebulium" I in distribution. The continuous spectrum varies in intensity over the nebula in a different way from that shown by the emissions, the greatest variation being from the nebulium lines N_1 and N_2. It is strongest in the region of the bright star Bond 734, but there is no reason to think that direct light from the star has appreciably affected the plate, for the star was kept at a safe distance above the slit. It is a question whether the star by reflected light or otherwise is not responsible for the intensification of the continuous spectrum. Unfortunately the bright hydrogen lines of the nebula of course would cover the absorption lines of hydrogen that might belong to the continuous spectrum of the nebula. However, the helium bright lines of the nebula are faint enough to allow the helium dark lines partially to reveal themselves. This is best seen in λ 4388, less well in λ 4472, as the latter tho absorptive on the east edge of the nebula becomes a faint bright line toward the west edge, turning the balance from absorption to emission. Thus there is some evidence that the continuous spectrum of this nebula is that of a B type star.

A spectrogram of the more distant nebula N. G. C. 1977 in the region of C *Orionis* was secured. Slit was E-W. This nebula is rather faint and the slit was wide on that account. The emissions of this nebula are still less numerous and fainter than are those of the previous nebula (N. G. C. 1982). The spectrum is a continuous one crossed by only a few of the strongest of the bright hydrogen lines; no other of the nebular emission lines are recognizable on the plate. The absence of the bright lines N_1 and N_2 give the spectrum a strange appearance. There are present, however, helium absorption lines crossing the continuous spectrum. These are more clearly present than they were on the plate of the preceding nebula.

Still more distant from the Great Orion Nebula about *θ Orionis* is the nebula N. G. C. 2068, located in a region remarkably devoid of stars, north and a little east of *ζ Orionis*. The spectrum of this object has also been photographed. Here even the hydrogen emissions fail and the spectrum is continuous, crossed by hydrogen and helium absorption lines, the former series strong, the latter weak, as in advanced B type stars. There are two or three stars involved in this nebula, and the nature of the spectrum suggests the interpretation the writer placed upon other similar cases: that the nebula is apparently illuminated by reflected star light. This object is in a region of the sky strikingly deficient in stars, which is true of the other objects giving spectra of this type. This implies that the light of the more distant stars is being absorbed by the nebula, which extends generally much beyond the evident limits of its luminous portion.

The spectra of these nebulae have been described in the order of their distances from the Great Nebula. The spectra, it has been seen, vary from the usual emission type of a gaseous nebula to the absorption type, with some sequence from one type to the other. If these nebulosities are to be regarded as parts of one great nebulous formation centering about the Trapezium, and it seems that they are really such, then the variation in the spectrum may be said to begin in the center with the usual emission type which loses strength (different substances differently) with distance outward and ends finally, in the most distant masses, with a continuous spectrum of the normal stellar absorption type.

Without doubt the spectrum of Pickering's encircling cloud would convey information of such value in nebular investigations as to be worth the effort to secure it even tho its faintness makes it an exceedingly difficult subject for the spectrograph.

WOMAN'S WORK IN ASTRONOMY[1]

HER WORK IN THE PAST, HER GREATER WORK IN THE FUTURE, HER DUTY TOWARD HERSELF AND HER OBLIGATIONS TO ASTRONOMY FOR THE BETTERMENT AND ENLIGHTENMENT OF MANKIND

BY DOROTHEA KLUMPKE ROBERTS

From the early ages of history unto the present times, in which the earthly abode of man has witnessed the most terrible of all catastrophes—Cain slaying his brother Abel on a world-wide scale—woman has appeared in the field of astronomy under the three-fold rôle of mother, priestess and helpmate. The mother of olden times, like the mother of our days, whether ignorant or wise, sad or joyful, stricken with poverty or blessed with worldly riches, has again and again glanced heavenward, and in her own fashion, untutored or tutored, has questioned the Sun, Moon and stars, imparting to the infant in her arms her love for things so great and marvelous in Nature that the sight of them filled her with reverence and awe.

It was not long in human history before the priestess appeared officiating in all sincerity and humility by the side of her husband, invoking with him the great power that they knew to govern this physical world of ours. Let us unroll the ancient papyri of the Egyptians and listen for a few brief moments to Hunefer, the scribe, and his wife Nasha, a priestess in the College of Aman Ra at Thebes, singing a hymn of praise to the rising Sun.[2] . . .

After the priestess, woman appeared as helpmate in the field of astronomy. She was the daughter, or the wife, or the widow, or the sister, or the niece, or the friend of the elect who, as civilization moved westward, consecrated themselves unto the study of Astronomy. I had the honor of invoking the memories of those faithful toilers and devotees of Science, in 1899, at a meeting of the Astronomical Society of France in Paris, on February 1st, and again, on July 29th, at the International Congress of Women held in London.

These tributes were published in the *Bulletin de la Société Astronomique de France* for 1899, and in the *Observatory*, published in London for August, 1899.

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[1] Read at the Pasadena meeting of the *Ast. Soc. Pac.*, June 19-21, 1919.
[2] Space limitations compel the omission of this hymn.

The names of those women and their astronomical labors are well known to all. I, therefore, shall not here recall them. Astronomers have honored them by giving feminine names to the planetoids, circling between *Mars* and *Jupiter*, the discovery of which dates from the beginning of the nineteenth century.

In these latter years the center of influence and power has been shifted by civilization unto the United States of America.

American astronomy is not yet one hundred and fifty years old. Professor Holden (*Smithsonian Annual Report*, 1899) says until the Revolution American science was but English science transplanted.

Astronomy along the Pacific Coast has been in existence for less than twenty-five years and the achievements attained are beyond all expectations.

In astronomy, as in every other branch of human knowledge, America is in the foremost rank, the whole world to-day looks unto her banner of stars and stripes for guidance and assistance.

The part performed by women in the American development is most praiseworthy. In astronomy, under the direction of her learned and eminent teachers she has proved herself not only most efficient in research work, but, being rich herself, she has endowed science with great riches, thus enabling research work to be carried on.

Women like Phoebe Hearst, like Catherine Bruce, like Anna Palmer Draper, women like Williamina P. Fleming, Annie J. Cannon, Harriet S. Leavitt were and are equally necessary to extend human knowledge far into space and time.

It is not only in the great observatories of the world that woman has distinguished herself, she proved herself equally gifted when on the computing staff, be it in Paris, at the Bureau des Longitudes, or in Washington at the office of the Nautical Almanac, or in Berkeley under the direction of Professor Leuschner. Those women computors—there are hundreds of them—recall with honor the women of the past such as Madame Lepaule in France helping Clairault in his computation of the orbit of Halley's Comet, Teresa and Madalena Manfredi assisting their brother, director of the Bologna Observatory, in astronomical ephemerides, or Margarthe Kirch rendering truly scientific services unto her German country.

At the various observatories of the world we now find women performing the duties of secretary, women translating scientific papers, women taking part in astronomical work, be it by direct observation or by photographic or spectrographic observation, we find women in the time service, as at the Paris observatory thruout and before the great war.

At the European observatories still engaged in the International photographic charting of the heavens, women have rendered service often without ever coming before the world's notice. At the Vatican Observatory for the last ten years the measurements of the astrophotographic plates have been intrusted to Italian nuns. At Potsdam, so close to Berlin, a British lady was employed for two or more years in measuring the astrophotographic plates of the Potsdam zone, assisted by a Prussian military official who inscribed the numbers. Miss Everett, having completed her work, returned to England.

In the higher educational centers, the American teacher finds herself equipped with an astronomical outfit that will be a source of inspiration to her European sisters when Europe, rejuvenated, rises out of its present convulsions.

At the Universities women attending courses in astronomy from a cultural point of view have, in a short time, acquired sufficient learning to enable them to write articles of esthetic and educational value.

And they who are at too great a distance to attend in person these courses in astronomy still are brought under the beneficial influence of astronomy by reading the monthly papers of the Astronomical Societies published thruout the world; the articles written and the observations made by women show what an uplifting subject of meditation the heavens are to them.

In the home, the wife of the astronomer has proved herself his worthy scientific and loving helpmate; what more beautiful example in these last years than that of the late Lady Huggins; Mrs. Walter Maunder in England; the late Madame Camille Flammarion in France; Mrs. David P. Todd and Mrs. W. W. Campbell in America. There are thousands and thousands of women like these. I cannot mention them all.

Useful and efficient as woman's work in astronomy may have been in the past, her work in the future will be far greater and more beneficial to the human race, for a sisterhood of all noble-minded women now encircles the earth. Out of this great war for Liberty, woman has arisen triumphant, she has taken possession of herself by giving herself in service unto others. Thruout these years and months of unspeakable human suffering, woman has been the ministering angel upon earth.

She knows that her duty unto herself is that of being a torch bearer of Truth. And what can be more helpful unto her in that sacred mission than the study of astronomy?

When woman becomes aware of what she owes unto astronomy, when she understands that all sciences contribute to the furthering of astronomy, when she but catches a glimpse of the wealth of information and the treasures of reward held in store for her by astronomy, then she will not rest until every child in every school thruout the world be taught with the a b c's the rudiments of astronomy.

Then she will confer with the directors of the boards of education and the directors of astronomical centers and she will see to it that astronomy be diffused among all classes of society. She will establish popular observatories such as the one Mr. Charles Burckhalter in Oakland is directing for the diffusion of learning. She will see to it that the toiling multitude of men and women who labor so hard during their working hours and who are so eager for enjoyment when the work is done, be instructed in astronomy and that they see depicted on the screens and on the films of the motion picture theaters to which they flock so readily, the wonderful creations of the universe which, up to the present time, have only been beheld by the privileged ones.

The multitudes will be taught where they are and what they are; in learning of their material and physical insignificance, they will become conscious of their moral greatness and the reign of the millennium will be at hand.

Then never again will there be found on earth hands nor minds nor hearts daring to desecrate the sublimest of all sciences by using her noble instruments as prototypes for destruction and annihilation

On the contrary, every human being, like the Egyptian princess Nasha, and her learned husband, Hunefer, the scribe, will daily greet and daily observe the Sun at his rising, daily observe the Sun at his setting, and will glance heavenward during the day and often thruout the night, inwardly singing praises of gratitude to the UNKNOWABLE ONE of which all things in heaven and on earth are but outward manifestations.

June 18, 1919.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1919

By Malcolm McNeill

Pacific "Summer" Time of the Phenomena may be obtained by adding one hour to Pacific Time.

PHASES OF THE MOON, PACIFIC TIME

First Quarter....	Sept. 2,	6^h22^m A.M.	First Quarter....	Oct. 2,	12^h37^m A.M.
Full Moon......	" 9,	7 54 P.M.	Full Moon......	" 9,	5 39 A.M.
Last Quarter....	" 16,	1 32 P.M.	Last Quarter....	" 15,	9 5 P.M.
New Moon......	" 23,	8 34 P.M.	New Moon......	" 23,	12 39 P.M.
			First Quarter ...	" 31,	5 43 P.M.

Autumn begins September 23rd, 6^h36^m P. M. Pacific Time, when the Sun crosses the Equator from North to South at the autumnal equinox.

Mercury is at its greatest west elongation on September 1st, being then a morning star rising about an hour and a half before sunrise. The conditions for visibility are good, but the elongation is much smaller than the average of greatest elongation as the planet reaches perihelion only five days later; also the apparent distance between planet and Sun diminishes rapidly and before the middle of the month the planet rises less than an hour before sunrise. *Mercury* reaches superior conjunction with the Sun and becomes an evening star on September 26th. By the end of October the planet is well out toward greatest east elongation, but conditions for visibility are not good, the interval between setting of the Sun and of the planet remaining less than an hour. *Mercury* is in very close conjunction with *Saturn* on September 10th, the least distance being only 0°7′, but unfortunately both planets are too near the Sun for naked eye observation.

Venus passes inferior conjunction with the Sun on September 12th, and becomes a morning star, and will continue as morning star until the summer of 1920. At the time of conjunction the planet is nearly 8° south of the Sun. This is nearly the maximum distance it can reach south of the ecliptic, the time of greatest heliocentric south latitude coming on September 10th; and as the real distance of the planet from the Earth is least at the time of inferior conjunction the apparent distance of planet from Sun at conjunction is nearly its maximum. The planet does not rise long enough before sunrise for naked eye visibility until well after the middle of September, but the interval increases rapidly, being two hours on October 1st, and more than three and a half hours on October 31st. *Venus* is again at its greatest brightness on October 19th, about half way between inferior conjunction and greatest elongation. It will be easily visible to the naked eye in full daylight for some weeks.

Mars is drawing far enough away from the Sun to be easily seen, altho it will not begin to be much brighter than its minimum until after the close of the year. On September 1st it rises shortly before 3 A. M. local mean time and shortly before 2 A. M. on October 31st. During the two months it moves about 37° eastward and 11° southward among the stars from *Cancer* thru *Leo*. On October 7th it passes less than 1° north of the first magnitude star *Regulus* (*Alpha Leonis*). It is also in conjunction with *Jupiter* on September 2nd, passing $0°41'$ north, and in very close conjunction with *Saturn* on October 24th, the least distance between the planets being only $0°5'$, this occurring about 4 A. M. Pacific Time.

Jupiter is still a morning object, rising shortly before 3 A. M. on September 1st, and shortly before midnight on October 31st, local mean time. It moves about 10° eastward and 3° southward from *Cancer* into *Leo*, being at the end of October about 12° west and north of the first magnitude star *Regulus* (*Alpha Leonis*). Its conjunction with *Mars* on September 2nd has already been mentioned. Also it is in conjunction with *Neptune* on September 22nd, being about the Moon's diameter north of the latter at the time of nearest approach.

Saturn is a morning star on September 1st, having passed conjunction with the Sun on August 25th, but does not reach a sufficient distance from the Sun for easy visibility in the morning twilight until nearly the middle of the month. At the end of October it rises at about 1^h30^m local mean time. Its motion is about 6° eastward and 2° southward in *Leo*, and on September 1st it is about 4° east of *Regulus*. The motion of the planet in its orbit is gradually bringing the plane of the rings nearer to the Earth, so that we see the rings more and more nearly edgewise, and the apparent diameter of the minor axis of the ring is only about one-tenth that of the major axis; as so little of the face of the ring is now turned toward the Earth, the planet is only about half as bright as it was during the early part of the year. Its conjunctions with *Mercury* on September 10th and with *Mars* on October 24th have been mentioned.

Uranus passed opposition with the Sun on August 23rd and is therefore in good position for observation. It is in the constellation *Aquarius* and moves slowly westward, about 1°30′ during the two months. Unfortunately there is no conspicuous star near the planet, so identification will not be easy. But on October 12th the planet is 1°23′ north of the fourth magnitude star, *Iota Aquarii*, and the planet will not be much more than 2° away from the star at any time during the period. A good star map will make identification of the planet not very difficult.

Neptune remains in the constellation *Cancer* and is above the horizon late at night, but is too faint for naked-eye observation.

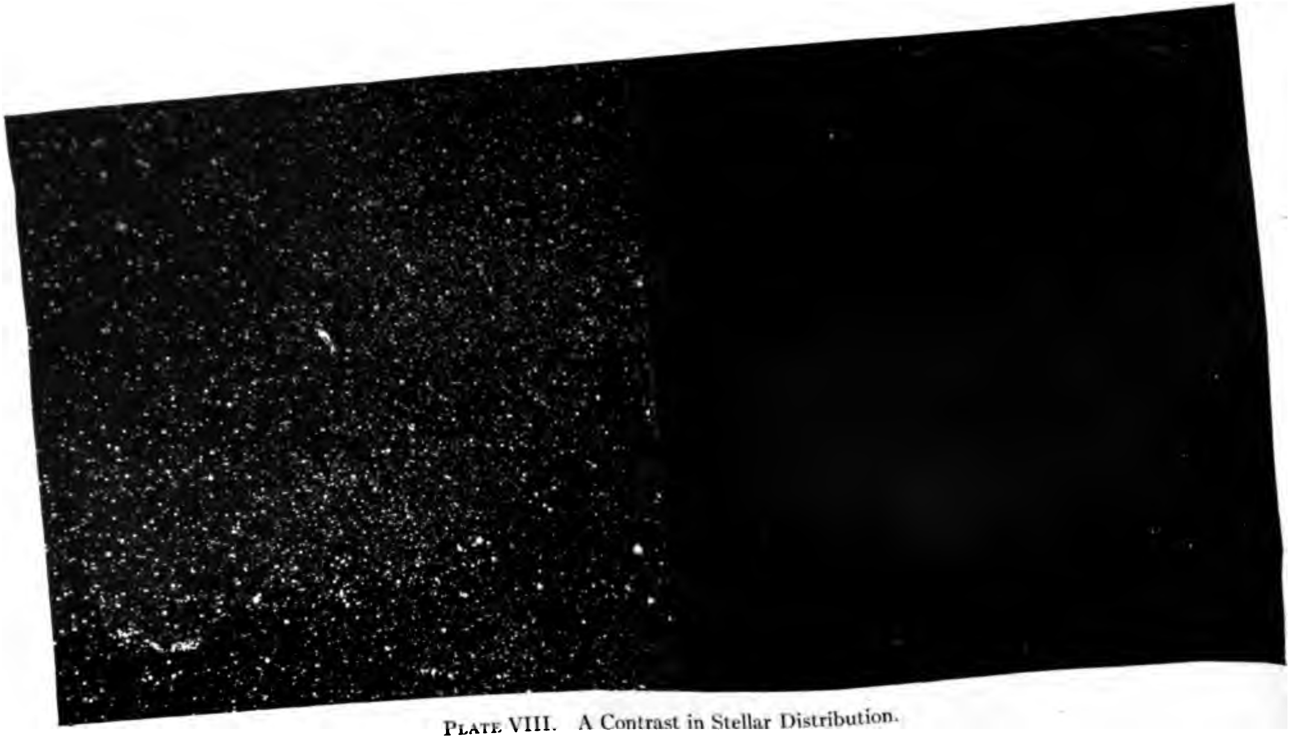


Plate VIII. A Contrast in Stellar Distribution.

NOTES FROM PACIFIC COAST OBSERVATORIES

A CONTRAST IN STELLAR DISTRIBUTION

A remarkable contrast in stellar distribution is shown in Plate VIII, facing this page.

Each half of the cut is half a degree on a side, so that the area of each part is 0.25 of a square degree. The area subtended by the disk of the full Moon, at its mean distance, is 0.21 of a square degree. Both plates were taken with the Crossley Reflector; the exposures were 1^h50^m in each case. The photographic enlargements from which the cuts were engraved were made by Mr. Carl Bergmann.

The upper portion of the plate shows a region of the Milky Way at 18^h4^m right ascension and 27°30′ south declination. This is one of the densest regions of the Milky Way thus far photographed with the Crossley Reflector. Counts on a number of small areas scattered over the plate indicate that there are at least 76,000 stars in the area covered by the cut. The very faintest stars in places form an almost continuous background which is lost in the reproduction.

The lower portion of the plate shows a starless region to the southeast of *θ Ophiuchi*, at 17^h24^m right ascension, and 25°30′ south declination. In this area of one-quarter of a square degree there are only 124 stars.

The two regions are a little more than nine degrees apart. It is very probable that the stellar desert shown in the lower cut is due, at least in part, to the presence of occulting matter.

HEBER D. CURTIS.

THE VARIATION IN SUN-SPOT ACTIVITY DURING THE PRESENT CYCLE

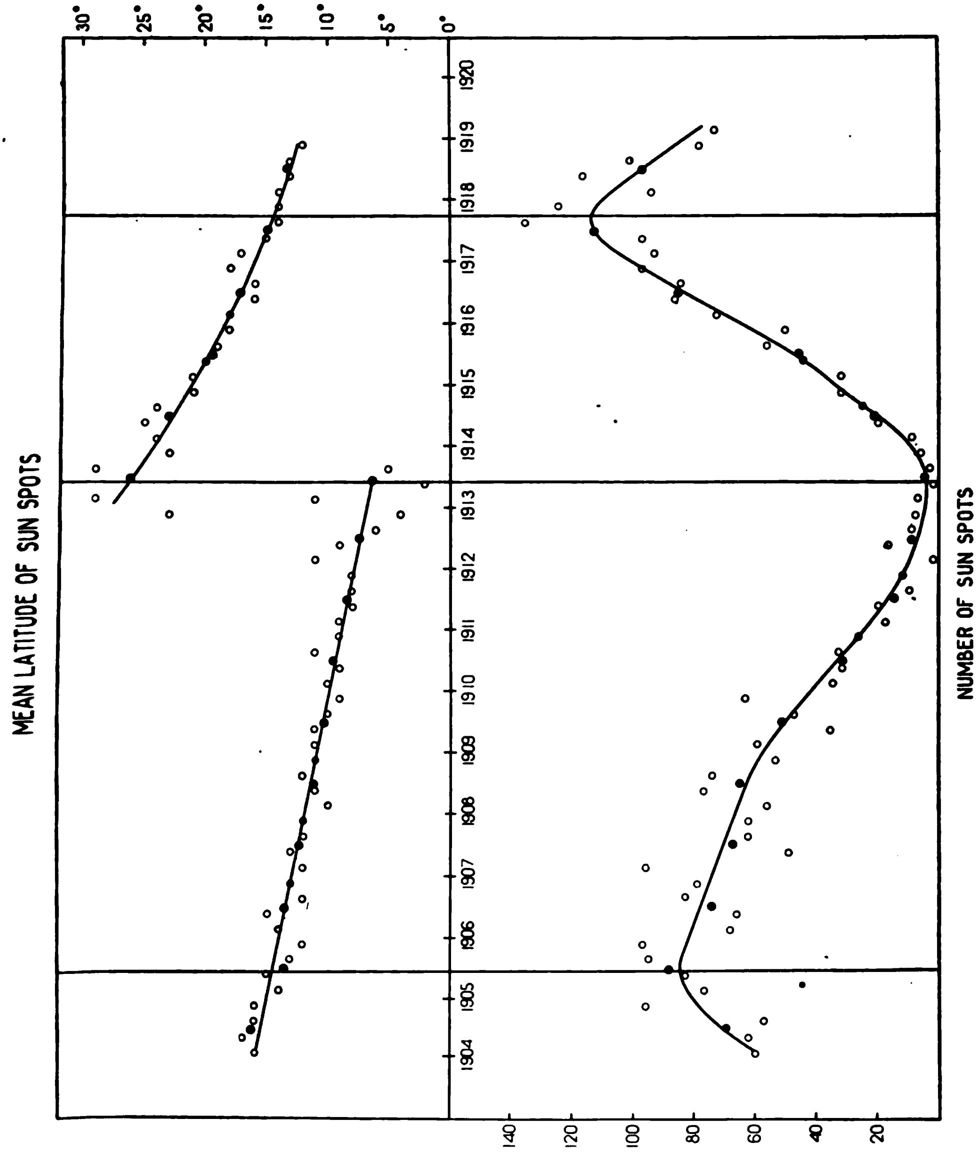
The sun-spot activity during the present cycle has been very typical in character, the variation represented in the lower curve of the figure showing very well the remarkable similarity to the light variation of Cepheid variables. In this curve the ordinates are the number of spot groups observed during three months, the open circles showing the number for the individual quarters and the black dots the average number observed quarterly during a whole year. A group has been counted as new when it appeared on the eastern limb so that recurrent groups have been counted once for each revolution of the Sun in which they were observed. The number of spots from 1904 to 1915 has been taken from the Greenwich observations; and since 1915 from the records of the Mount Wilson Observatory.

The period of the last cycle as indicated here was about 12.5 years, which is somewhat longer than the average for the last few cycles, the time from maximum to minimum being about one year greater than the average. This was due principally to a rather prolonged minimum altho it comes in part from the time assigned for the 1905-1906 maximum, several observers having placed it later than indicated here. This may be due to the different method of measuring spot activity, the average daily "Wolf number" or the mean daily "spotted area" being the usual gauge of activity.

Maximum occurred about August, 1917, the most active quarter being July, August and September, 1917, during which time one hundred and thirty groups were observed. The activity was appreciably greater than during the maximum of 1905-1906. The decline apparently has been rather rapid, January, February, and March of this year giving only ninety-three groups. However, the variation of individual quarters from the mean curve is large and an increase of activity for a few months, of which there is evidence, would raise the mean curve considerably.

The upper curve of the figure shows the variation in the mean latitude of the sun-spot zone. Open circles indicate the average latitude of spots during a quarter of a year, the black dots the average latitude for a whole year. The decline in latitude toward the minimum and the revival of activity in high latitudes is a well-known characteristic. At any one time the sun-spot zone is several degrees wide (about 25 degrees). At minimum there are, of course, very few spots, so that the zones are not well marked, but there is distinct evidence of two zones, one with a maximum activity at about 27 degrees and the other at about 7 degrees latitude. It is interesting to note that at maximum activity the average latitude of sun-spots is about 14 degrees.

The past maximum was marked by two groups of remarkable size, each covering about 3300 millionths of the visible hemisphere of the Sun. The first of these, which appeared in February, 1917, was a bi-polar group of comparatively simple structure. The second large spot group, in August, 1917, was very complex and


MEAN LATITUDE OF SUN SPOTS
30°
25°
20°
15°
10°
5°
0°
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
140
120
100
80
60
40
20
NUMBER OF SUN SPOTS

appeared at a time when the Sun as a whole was extremely active. A photograph of the Sun showing this group somewhat past its prime was reproduced by Mr. Ellerman in the February number of these PUBLICATIONS (Plate I). The only rivals of these two huge groups, which have been observed during the past half century, were in February of 1892 and 1905, respectively.

SETH B. NICHOLSON.

NINETEEN NEW VARIABLE STARS

In the course of a study of the magnitudes of the southern globular cluster Messier 68 (N. G. C. 4590; R. A. $= 12^{h}34^{m}.2$, Decl. $= -26^{\circ}12'$, 1900.0), a number of stars of the sixteenth magnitude were found by Miss Ritchie to vary in light. The following list gives the position of the variables with respect to the center.

POSITIONS IN VARIABLES IN MESSIER 68

Star No.	x	y	Star No.	x	y
1	−4′40″	+1′49″	11	+0′19″	−1′36″
2	−2 48	−0 45	12	+0 33	+1 10
3	−2 20	+1 31	13	+0 48	+0 8
4	−1 57	−2 11	14	+1 1	−0 22
5	−0 56	+2 50	15	+1 4	+6 20
6	−0 31	+0 40	16	+2 21	+2 3
7	−0 4	+3 38	17	+2 38	−0 44
8	+0 9	+0 58	*18	+6 20	+4 23
9	+0 11	+1 20	19	+7 20	+2 40
10	+0 16	−1 15			

Variable No. 18, one of the brightest stars in the cluster, appears to have a long period. All the others are probably typical cluster-type variables. Their amplitudes are of the order of one magnitude and their periods are short.

The median brightness of these short-period variables is between one and two magnitudes fainter than the brightest cluster stars, closely agreeing in this respect with the results for other clusters that contain Cepheid variables. A study of the light variations, therefore, will yield an accurate value of the parallax and absolute magnitudes for all the stars in the cluster. HARLOW SHAPLEY.

THE "NEW STAR" IN SERPENS, 7.1917

Two years ago, while photographing the position of the asteroid *Boliviana*, Professor Wolf found an image (magnitude 9.0 on the B. D. scale) that was not recorded on any of his plates prior to 1910 (*A. N.*, **204**, 293, 1917). Visual observations by Mündler and Wolf verified the star's existence but showed no variation in light. Later the designation 7.1917 was assigned to the object.

The position for 1917.0, determined by Mündler (*A. N.*, **204**, 344, 1917), is

$$\left.\begin{array}{ll}\text{R. A.} & 17^{h}35^{m}13^{s}.45\\ \text{Decl.} & -11^{\circ}53'57''.6\end{array}\right\}\text{(Epoch of 1917.45)}$$

Hoffmeister, observing visually for sixteen months, found no conspicuous variation in light (*A. N.*, **208**, 244, 1919). More recently Wolf has published a list of forty-one plates dating from 1895 to 1917; none of the twenty-nine before July, 1910, shows the star, and none of the later ones fails to record it (*A. N.*, **208**, 363, 1919).

Not knowing of the earlier discovery and discussion, Professor Barnard independently found the star a few months ago and has published three notes concerning it (*Astronomical Journal*, Nos. 749 and 750; *Popular Astronomy*, **27**, 374, 1919). With the assistance of Harvard plates dating from 1891 he finds that the star appeared between June 29, 1908, and July 9, 1909.

The spectral type as determined at Mount Wilson is F0; the radial velocity is large and positive.

This object appears to me to be one of the most remarkable on record. While at present it is difficult to decide which hypothesis is preferable, three possible interpretations of the star may be suggested:

1. A new star evolving from a non-luminous, nebulous beginning.
2. A long-period or irregular variable of a new kind.
3. A normal invariable star coming from behind obscuring nebulosity.

The star is called a variable by Wolf, Barnard, and Bailey, but the evidence now in hand, I believe, would rather justify the name "new star," using that designation in a different and better sense than when applied to Novae. The Novae, more appropriately "temporary stars," are probably now considered by no one to be forerunners of typical stars. Before the outburst of light, they frequently, probably always, exist as stars of a brightness not much less than the magnitude to which they slowly return. They appear to be occasional stellar catastrophes—possibly indeed the forerunners of planetary nebulae and dwarf O-type stars. But it seems likely that the ancestry of the innumerable ordinary stars must be sought in phenomena of a different sort.

The birth of a typical star (that is, the pre-giant stages in Russell's theory of spectral evolution) is not yet on record, so far as we know. It may be, as pointed out in *Mount Wilson Contribution*, No. 156, that we have failed to find embryonic stars because either the genesis is now complete, or it is occurring in regions not under observation, or, more reasonably, wherever and whenever it occurs the pre-giant stage passes so quickly, compared with the later spectral development, that our relatively short records fail to show for a single stellar object the growth from obscurity to full and fairly constant brilliancy. This last point of view is supported by Russell's interesting discussion of the sources of stellar energy, printed on a preceding page of this issue. The rapid "birth," according to his suggestion, occurs during the time when the star's radiative energy emanates solely from gravitative sources; the much slower development then proceeds at the expense of internal "unknown" sources of energy.

Probably, therefore, the beginning of a star should show relatively rapid secular increase in light from invisibility to the stage where for that particular stellar mass the immeasurably slow process of ordinary stellar evolution sets in; the beginning should be represented by a "Nova that maintains its maximum brightness." In the object 7.1917 we appear to have the first well-authenticated case of such an occurrence, and hence the unusual significance of the star. There have been instances of stars, not recorded in the earlier surveys, that are now sufficiently bright to have been included. Probably these omissions are rightly attributed to error, oversights in the earlier work, or small secular changes in brightness, rather than to the appearance of new stars of permanent maximum magnitude.

Neither the spectral type of 7.1917 nor its brief ascent to maximum is decisive against the supposition that it is literally a new star; but a redder type would appear more natural (at least, at the beginning of visibility ten years ago), and a somewhat slower increase of light might have been expected, altho the purely gravitational contraction of a gaseous star is very rapid, according to modern views.

Both the color and spectral type are decidedly opposed to the hypothesis that the star is a long-period variable. The shape of the light curve would also be distinctly anomalous for that interpretation.

The spectral type, the high velocity, and the star's position in the southern Milky Way, not far from some of Barnard's dark markings, all would favor the supposition that the star has just emerged from behind an obscuring nebulosity. As a possible test of this assumption, on June 23rd of this year, under very favorable conditions, I made with the 60-inch reflector an exposure of two hours on a Seed 30 plate. Stars much fainter than the eighteenth magnitude are shown within 15″ of the new star, but no trace of nebulosity appears.

By superposing a réseau upon the above mentioned photograph and upon others of shorter exposure, the number of stars per square minute of arc was determined. The results for magnitudes 17.5-19.0 appear in the following tabulation, which is symmetrically arranged with respect to the new star. It is difficult to decide if the uneven density in the center indicates the presence of local obscuration.

NORTH

	19	10	11	14	10	16	18	15	14	17
	13	16	15	15	12	8	18	14	8	14
	10	17	15	15	15	11	12	15	16	12
	9	21	13	17	10	14	17	17	17	13
	9	14	19	19	12	22	26	21	16	25
WEST					x					
	10	16	11	10	10	12	13	22	18	14
	14	20	16	17	12	20	25	26	17	15
	17	14	20	25	25	19	19	21	24	17
	26	19	17	19	20	17	21	16	23	17
	14	15	18	22	19	18	13	21	15	19

For areas of one-fourth of a square minute of arc the means of counts in the immediate vicinity of the new star by Miss Ritchie and the writer are as follows:

NORTH

	6	4	4	4	7	2	5	2	2	6
	3	5	3	2	4	3	2	2	5	6
	3	4	6	4	3	5	2	3	7	2
	5	4	6	3	4	6	6	5	4	4
	6	6	4	4	2	4	4	7	5	6
WEST					x					
	4	4	2	3	4	2	6	5	4	6
	7	2	2	4	2	5	1	4	6	4
	4	6	3	4	2	10	6	4	7	5
	2	4	4	4	3	2	2	7	6	4
	4	6	7	6	6	5	6	6	2	6

On the basis of an estimate of the absolute magnitude by Mr. Joy, the distance of 7.1917 is found to be of the order of 500 parsecs. The star therefore probably lies well beyond the nebulosity that is supposedly associated with the neighboring bright stars of the moving group in *Scorpio*.

As a matter of record the photographic magnitudes of 25 faint stars near the new star are given below, basing the determinations on a series of Mount Wilson plates. On the supposition of a moving nebulosity, these values may in the future serve as a test for further conspicuous change in the brightness of stars of this particular field.

MAGNITUDES IN THE FIELD OF 7.1917

Star	Pg. Mag.	*x*	*y*	Star	Pg. Mag.	*x*	*y*
1	14.47	−1′56″	+4′25″	14	16.7	+0′ 9″	−1′ 5″
2	14.84	+5 10	−0 49	15	16.7	−1 21	+0 36
3	14.90	−4 45	+2 52	16	16.8	−0 57	+0 15
4	15.14	+1 27	−3 16	17	16.8	+1 28	+0 42
5	15.34	−3 3	+0 15	18	17.1	−0 26	−0 10
6	15.40	+4 49	+1 34	19	17.3	−0 16	−0 2
7	15.40	+5 7	+2 3	20	17.3	+0 4	−0 38
8	15.42	−3 18	−0 4	21	17.6	+0 14	−0 14
9	15.46	+4 56	+2 36	22	18.1	+0 14	+0 6
10	15.78	+4 39	−1 10	23	18.3	−0 20	+0 1
11	15.90	−0 33	+0 4	24	18.3	−0 16	−0 26
12	15.94	+0 38	+0 46	25	18.6	−0 12	+0 4
13	16.0	−1 41	−1 22				

The photographic and photovisual magnitudes of the new star and of a few surrounding stars of the B. D. will be reported at another time when better values can be given. It now appears that the star is not brighter than the eleventh magnitude on the Mount Wilson photographic system.

The Harvard plate of July 9, 1909, is the first to show the star. From Wolf's data I believe we can say that the star did not appear before the ninth of the preceding month. Reducing to a common zero point the magnitude estimates made at Harvard and Heidelberg and calling the maximum photographic value 11.0, I obtain for the years when the star was brightening the following approximate data, which may serve as a condensed photographic history of the star's light.

1908, May 20,	fainter than 15	Leavitt	1910, June 3,	11.3	Wolf
June 3,	fainter than 16	Wolf	4,	11.5	Leavitt
1909, May 18,	fainter than 16	Wolf	29,	11.6	Leavitt
June 9,	fainter than 15	Wolf	Aug. 7,	11.4	Wolf
July 9,	14.4	Leavitt	1911, May-July,	11.6	Leavitt, Wolf
24,	fainter than 13	Wolf	1912, July,	11.5	Leavitt
Aug. 16,	fainter than 11.5	Leavitt	1913, May-June,	11.3	Leavitt, Wolf
1910, Mar. 21,	11.3	Leavitt	1914, June,	11.1	Leavitt, Wolf
Apr. 12,	11.7	Leavitt	1915, Apr.-July,	11.0	Leavitt, Wolf
15,	11.6	Leavitt	1916, May,	11.0	Leavitt
May 16,	11.7	Leavitt	1917, May-Aug.,	11.0	Leavitt, Wolf
19,	11.5	Leavitt	1918, June-Aug.,	11.0	Leavitt

HARLOW SHAPLEY.

THE MASSES AND ABSOLUTE MAGNITUDES OF VISUAL BINARIES[1]

Our knowledge of the masses of the stars is derived mainly from double stars. Altho several methods have been devised for their determination, the principal way to derive masses for individual systems without any assumptions is applicable to those visual binaries for which both the orbit and the parallax have been determined. In such cases we have

$$m_1+m_2=\frac{a^3}{\pi^3P^2},$$

in which $m_1 + m_2$ is the only unknown quantity, a, π, and P being semi-major axis, parallax, and period, respectively.

During the last few years both the number and the quality of stellar parallaxes have been greatly improved; a new attempt is being made, therefore, to enlarge our knowledge of the masses of the stars. For the orbits of the binaries I have used the data recently published by Aitken in Table I of his book, "*The Binary Stars*"; for the parallaxes all the material now available has been employed, including unpublished spectroscopic parallaxes which Dr. Adams has kindly allowed me to use for this purpose.

Fifty-five binaries, whose orbits are known with at least fairly good approximation, have available parallaxes, and for each of these the weighted mean parallax has been determined. Modern observations, such as those by the Yerkes, McCormick, and Sproul Observatories, were given weight 1; others were assigned weights according to their probable errors. Twenty-six stars have parallaxes with weights > 3, sixteen have weights 2-3, and the others have weights < 2. In order to make the results more reliable, stars were excluded when the percentage probable error in the parallax exceeded fifty per cent in the first class, twenty-five per cent in the second, and ten per cent in the third. This process leaves thirty-nine binaries for which we may accept the parallax as at least fairly well determined.

For each system $m_1 + m_2$ and the absolute magnitude M were computed. The results are given in the table, arranged according to spectral type and absolute magnitude.

For two stars the masses surpass 20 times that of the Sun; for *β Delphini* $m_1 + m_2$ is not less than 45.7, and for Σ 1835 it is 26.1.

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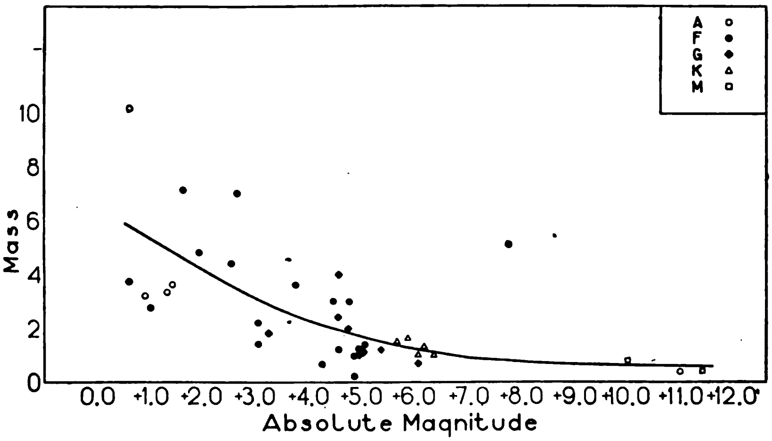
[1] Read at the Pasadena meeting of the *Ast. Soc. Pac.*, June 19, 1919.

A				F				G				K				M			
M	Mass	w	p.e.	M	Mass	w	p.e.	M	Mass	w	p.e.	M	Mass	w	p.e.	M	Mass	w	p.e.
				−0.1	45.66	3.2	27%												
+0.6	10.29	4.9	27%	+0.6	3.76	5.2	35%												
+0.9	3.23	2.2	4%																
+1.3	3.31	0.7	1%	+1.0	2.77	3.0	45%												
+1.4	3.61	4.4	21%	+1.6	7.33	5.0	28%												
+1.6	26.09	3.0	14%	+1.9	4.87	5.0	18%												
				+2.5	4.41	5.6	14%												
				+2.6	7.29	2.5	8%												
				+3.0	1.37	3.7	3%	+3.2	1.65	4.2	11%								
				+3.0	2.19	5.0	11%												
				+3.7	3.60	4.4	14%												
				+4.2	0.69	2.0	10%	+4.5	4.00	2.0	16%								
				+4.4	2.95	2.2	15%	+4.5	2.38	5.0	40%								
				+4.5	1.18	3.4	5%	+4.7	2.01	0.5	1%								
				+4.7	2.94	3.0	18%	+4.9	1.17	3.2	12%								
				+4.8	0.18	2.0	18%	+4.9	1.09	2.0	8%								
				+4.8	0.90	3.6	13%												
				+4.9	1.17	8.3	2%												
				+5.0	1.43	3.2	16%	+5.3	1.22	3.1	5%	+5.6	1.53	2.7	23%				
												+5.8	1.63	7.6	3%				
								+6.0	0.73	5.1	10%	+6.0	0.96	4.2	6%				
												+6.1	1.34	2.6	8%				
												+6,3	1.09	2.7	15%				
																+ 9.9	0.88	4.0	5%
+10.9	0.44	2.9	8%																
																+11.3	0.43	2.3	2%

In the first case the parallax is found to be $+0''.015 \pm 0''.004$, weight 3.2; for Σ 1835, $\pi = +0''.007 \pm 0''.0015$, weight 3.0. Altho for both binaries the percentage probable errors are small, the parallaxes themselves are also so small that not much weight should be attached to these results. It seems quite probable that later determinations of parallax for both stars may greatly alter the computed masses; I have therefore excluded both from the following discussion.



In the accompanying figure the masses are plotted as ordinates against the absolute magnitudes as abscissae; the correlation appears independent of spectral type. The smooth curve, based on the means of 3 and 4 stars, gives the best observational relation now obtainable between mass and absolute magnitude.

To investigate a possible relation between mass and velocity, Miss Burwell kindly furnished me the radial velocities (corrected for the Sun's motion) of 34 of the 37 systems shown in the diagram. The dispersion of the velocities for systems of about the same mass, as well as that of the masses for stars with nearly the same velocities, is so large as practically to efface any relation between these two quantities. Taking the means of eight or ten stars we find some evidence, however, that in the mean the larger masses have smaller velocities. The change in velocity is from 17 to 22 km/sec for a decrease in mean mass from 6.21 to 0.65 that of the Sun. Grouping the stars according to velocities, we find an indication that the larger velocities belong to stars with small mean masses.

A. VAN MAANEN.

PRELIMINARY PARALLAX OF NOVA AQUILAE NO. 3[1]

Eleven exposures were measured by both van Maanen and Sanford to derive a preliminary parallax of the Nova. The result is

$$\pi \text{ abs.} = +0''.060 \pm 0''.004$$

The first two exposures were taken on June 12, 1918, when the magnitude was +0.7; altho a double rotating sector was used at that time in order to cut down the brightness of the Nova, the exposures still show images of considerable size, about 6″ in diameter. Using only the later exposures we can compute the parallax by adopting the proper motion that was derived by Trumpler; we then find +0″.058 ± 0″.007.

Altho the parallax is still uncertain it seems worth while to compute the absolute magnitude of the Nova at different epochs. By accepting +0″.060 as parallax, the absolute magnitude at maximum was −2.4; now it is about +5, and, supposing that the apparent magnitude will diminish to 10.5, which was the value before the outburst, the absolute magnitude will be +9.4 at minimum. For the three Novae for which parallaxes are available (*Nova Persei* No. 2, *Nova Geminorum* No. 2, and *Nova Lacertae*), the mean absolute magnitudes are −2.9 and +6.9, respectively, at maximum and minimum, in good agreement with the results above.

On June 4, 1919, the Nova had the appearance of a very small planetary nebula, the disk being a little over 1″ in diameter.

A. VAN MAANEN AND R. F. SANFORD.

NOTE ON THE RESULTS OF THE SEARCH FOR AN INTRA-MERCURIAL PLANET, ECLIPSE OF JUNE 8, 1918.

Two of the cameras of the Vulcan-Einstein apparatus employed at Goldendale, Washington, were directed about 4° east and west of the Sun in continuation of the search for an intra-Mercurial planet.

Fifty-eight stars were found on the two Einstein plates taken with the Sun central, limiting magnitude about 9.0 B. D. On the plate of the region to the west of the Sun sixty-five stars were found; a few of these were as faint as 9.0. But on the plate directed to the east of the eclipsed Sun only one star was found, and that at the very edge of the plate nearest to the Sun; clouds cut out all others. On this plate even a star as bright as magnitude 3.1 is invisible.

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[1] Read at the Pasadena meeting of the *Ast. Soc. Pac.* June 19, 1919.

The result of the search for an intra-Mercurial planet near the Sun at the eclipse of June 8, 1918, may then be summed up as follows: In an area approximately 5° wide, extending from 2° east to nearly 6° west of the Sun, there was found no suspicious object as bright as magnitude 8.5. The area just described represents quite accurately the size of the fortunate hole in the clouds thru which the eclipse was observed, as some cutting off is suspected at the outer corners of the western plate. HEBER D. CURTIS.

A PERIODIC TERM IN OBSERVATIONS OF RIGHT ASCENSION[1]

Observations of a fundamental character made with the meridian circle at the Lick Observatory in the years 1905 to 1908 exhibit differences in the transits recorded by chronograph similar to those noted by Mr. Zimmer at Cordoba in 1917 and 1918.[2]

Our determination is based upon three sets of comparisons of clock corrections observed at various hours of the day and night, which may be combined in groups to show the relative difference between transits near sunrise and sunset. In the first set there are twenty comparisons of the results from two groups of stars differing twelve hours in right ascension, in which the observed correction from one group is compared with the correction interpolated from the observed corrections of the other group. The interpolation of the rate is for half a day in each case. These observations were made in 1905 and 1906, and from the same series there are thirty-six comparisons of the clock correction from α *Andromedae* with the corrections from the group of stars fourteen hours later. The Dent Sidereal clock (No. 4) was in use at that time.

The third series was made in continuous periods of observing of two days each, each period containing four groups of stars with six hours in a group, observed twice when possible. Mr. R. F. Sanford and I alternated in the observing of September and October, 1907, and April, 1908, the bad weather in the spring of 1908 having prevented the observations of a fourth period as planned. There are twelve comparisons in this series between groups of stars differing by twelve hours of right ascension. The Riefler clock (No. 5) was in service for these observations, running under constant atmospheric pressure (barometric). All comparisons give approximately the same mean results—sunrise transits recorded relatively later than those at sunset by $0^s.05$.

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[1] Abstract presented at the Pasadena meeting of the *Ast. Soc. Pac.*, June 19-20, 1919.

[2] *Astron. Jour.*, **32**, 1, 1919.

There is no probability that any sensible part of this difference is due to the parallax of the stars observed. The effect is too great, of the order $0''.3$ to $0''.4$, for the average of the stars. Many attempts have been made to observe for parallax with the meridian circle in this manner, the earliest on record being that of Roemer at Copenhagen, over two hundred years ago. The differences found in the early results were shown to have been undoubtedly due to periodic variations in the daily rates of the clocks, between the hours of day and night. With our modern clocks very accurately compensated for changes of temperature, and in many cases protected from the effect of variations in atmospheric pressure, no large daily periodic fluctuations in rates should be anticipated. The amplitude of the changes under discussion is, however, very small, and there are other conditions than changes of temperature and pressure that may slightly affect the rate of a good clock.

Since various observers at different locations find similar periodic variations in clock corrections, the cause is more likely to be found in some of the observing conditions, rather than in the rates of the clocks used. The change in the refraction in zenith distance which occurs here and at San Luis, between day and night, may be accompanied by a horizontal component of disturbance at the critical epochs of sunrise and sunset. The effect might be explained by a tilting of the air strata, due to the heating of the upper atmosphere before sunrise, when our surface record of temperatures would lag behind that corresponding to the conditions of the whole atmosphere above us. At sunset the heating of the upper air strata would lag behind the exposure of the surface strata.

In zenith distance the total change between day and night is about one per cent of the total refraction, the change occurs during periods preceding and following sunrise and sunset of about two hours each side of those epochs, and the effect at those epochs would be about half the total change. This effect would be of nearly the same order as that of a possible horizontal component, a refraction disturbance that has always been evident in geodetic observations of long lines at various hours of the day. The disturbance in geodetic observations is generally less noticeable just preceding sunset than at other hours. R. H. TUCKER.

Visitors at the Lick Observatory

During the past few weeks the Lick Observatory staff have had the pleasure of visits from the following scientists:

Dr. E. F. Pigot, S. J., Director of Riverview College Observatory, Sydney, New South Wales.

Professor William A. Bryan, zoölogist and ornithologist, Professor of Zoölogy in the College of Hawaii.

Ingenero Pedro C. Sanchez, Director of the Mexican Geodetic Commission, Tambaya, Mexico.

Señor don Ismael Magaña of the Mexican Consulate in San Francisco.

Mr. C. C. Smith of the Dominion Astronomical Observatory, Ottawa, Canada.

Dr. E. A. Fath, President of Redfield College, Redfield, South Dakota.

Mr. Carlos Mundt, teaching fellow in the Berkeley Astronomical Department, was a voluntary assistant at the Lick Observatory during the month of June.

GENERAL NOTES

The Pasadena Meeting of the Pacific Division of the American Association for the Advancement of Science.—The third annual meeting of the Pacific Division of the American Association for the Advancement of Science held in Pasadena, California, June 19-22, like its predecessors, was a marked success, both in the matter of attendance, the high class of the scientific papers presented, the interest shown, and the careful arrangement for the entertainment of all those present.

Sessions of the affiliated societies were held in the hall of Throop College, Pasadena, on Thursday and Friday mornings, none being planned for the afternoons, in order to give the members an opportunity to attend the two Symposia of the Association. The first of these was under the auspices of the Western Society of Naturalists, and the problems involved in the projected exploration of the North Pacific Ocean were ably presented by eight specialists in this field. The symposium of Friday afternoon was devoted to "Scientific Education in a Democracy," each of the seven speakers presenting some new phase of the scientists' opportunity and responsibility in the solution of the problems presenting themselves in the readjustment to peace conditions.

It is to be hoped that the plan of devoting the afternoons to general sessions of the Association will be continued, inasmuch as these are one of the most important features of scientific gatherings, affording as they do an opportunity of mingling with and hearing specialists in all the different fields of investigation.

The address of the retiring president of the Pacific Division, Dr. D. T. MacDougal, on the "Growth of Organisms," given on Thursday evening in the Palm Room of Hotel Maryland, was listened to by a large and appreciative audience. Dr. MacDougal dealt in a masterly way and in a manner especially interesting to his audience with one of the most difficult and at the same time most fascinating problems of science, the fundamental processes of life development. A summary of his conclusions, presented in this address, will be found in the number of *Science* for June 27th, and is particularly commended to our readers.

As one of the participating societies, the Astronomical Society of the Pacific held two sessions for the presentation of scientific papers. Dr. Dorothea K. Roberts, the second vice-president of the society, presided over the meeting on Thursday morning, and Dr. J. A. Anderson, of the Mount Wilson Observatory, presided at Friday morning's session. Both sessions were well attended, there being a good representation of astronomers from the Pacific Coast and a lively interest was shown in the numerous lines of investigation described.

In addition to the twenty-eight papers in the preliminary program printed in the June, 1919, number of these PUBLICATIONS, the four following were presented:

(1) On the Sources of Stellar Energy, by Henry Norris Russell.
(2) Dispersion Tables for B-type Stars, by H. Thiele.
(3) Preliminary Parallax of *Nova Aquilae* No. 3, by A. van Maanen and R. F. Sanford.
(4) A Periodic Term in the Observations of Right Ascension, by R. H. Tucker.

The public address of Friday evening was given by Professor S. D. Townley on "Earthquakes on the Pacific Coast of North America," a subject with which Dr. Townley is thoroly conversant, and knows how to make especially interesting to his audience. In this lecture special attention was given to the consideration of the cause of earthquakes so far as known, and to the form of construction of buildings required in earthquake regions.

Through the courtesy of Throop College of Technology, excellent luncheons were served in the college dormitory to all visiting members on Thursday and Friday. The social intercourse of the noon hour, the renewal of old acquaintances and the forming of new ones, was one of the pleasant features of these meetings.

Among so many things of interest it might be difficult to pick out that which impressed one the most; but the visit, on Saturday, to the laboratories and shops of the Mount Wilson Observatory and to the Observatory itself on the summit of Mount Wilson, must have appealed to all the members, and certainly to those interested in astronomy, as the fitting climax of the Pasadena meeting.

Every moment of the day and a good part of the night was fully occupied; there were the beautiful photographs of nebulae, of spectra, laboratory, solar and stellar; demonstrations were given by members of the staff of the working of the tower telescopes with their powerful spectrographs and spectroheliographs; and of the 60-inch and 100-inch reflectors. At the noon hour a buffet luncheon was served on the grounds of the Observatory.

Naturally interest centered on the new 100-inch telescope, now practically completed. At four in the afternoon the visitors, to the number of about two hundred, assembled in the great dome and listened to an illustrated lecture by Director Hale on the work of the Observatory. He stated that while the first equipment of the Observatory was designed for solar work alone, it had not been their intention to devote observations to the Sun alone, but to bring to the study of this typical star information gathered from the other stars, and for this purpose the 60-inch and finally the 100-inch reflector had been constructed. Among the many lines of investigation for which the great light gathering power of this instrument will be utilized is the one, long cherished by Dr. Hale, of photographing the spectra of at least the brighter stars with stationary spectrographs comparable in dispersion with those used on the Sun. One is impressed with the ease and rapidity with which this massive instrument is manipulated and the manner in which all the numerous and difficult engineering problems have been successfully met. Those who remained during the evening had an opportunity of seeing several objects with the large telescope and, for all, these were wonderful views. The visiting astronomers present, several of them men familiar with the best that existing telescopes can do, were filled with admiration for the magnificent definition given by this instrument. In their judgment the definition given by the 100-inch is not only satisfactory, but of the very best. Director Hale and his able staff are certainly to be congratulated on this splendid instrument. Theirs was not only the responsibility of design, but the actual work of construction, as the mechanical (except the very massive ones) and optical parts were made in the Observatory shops. In due time we shall expect to see the hopes of its makers fully realized in the important scientific results obtained by the aid of this telescope.

I feel sure that the members would all wish to join me in expressing our appreciation to Dr. amd Mrs. Hale of the delightful garden party given in honor of the visitors at their home on Friday evening. The Association is also under deep obligation to the director and staff of the Mount Wilson Observatory, to the president and faculty of Throop College, and especially to the very efficient committee on arrangements, for the attention and many courtesies which contributed so largely to the success of this meeting.

J. H. Moore.

Corrections to the Adolfo Stahl Lectures in Astronomy.—In order to avoid a possible misunderstanding regarding the nature of the tests made upon the 100-inch mirror during the process of figuring the following modification of the wording of the description contained in the third paragraph on page 250 of the *Adolfo Stahl Lectures in Astronomy*, is suggested:

". . . . Visual optical tests were made each morning after a day's figuring; frequently repeated tests on different days were necessary before figuring could be resumed. These tests were made both at the center of curvature and at the focus of the paraboloid; the former method is better for determining the figure of the mirror as a whole, while the latter test is invaluable for detecting and correcting zonal errors in the general curvature. At intervals during the figuring the Hartmann method of testing was also used, the measurements of the photographic plates by Mr. Adams furnishing explicit data regarding the figure of the mirror. . . ."

In referring to the black notch in the nebula extending south from *Zeta Orionis*, the statement is made, on page 167, that "This particular marking has not, so far as I am aware, been photographed before." Professor Barnard, in a kindly letter, has given me references to several earlier photographs showing this feature, including one by Dr. Isaac Roberts taken January 25, 1900, and reproduced in the *Astrophysical Journal*, Vol. 17, Plate IV, p. 76; and one by himself, reproduced in the negative form in Vol. 38, Plate XX, p. 496, of the same journal.

The caption for figure 9, p. 128, should read "Eratosthenes' Method of Determining the Size of the Earth."

R. G. AITKEN.

The French minister of education has named as American correspondents of the Bureau of Longitudes, Dr. George E. Hale, director of the Mt. Wilson Observatory; Dr. William Wallace Campbell, director of the Lick Observatory; and Professor William S. Eichelberger, director of the U. S. Naval Observatory.

Dr. George E. Hale has been elected a foreign associate of the Paris Academy of Sciences, a distinction previously conferred upon only two Americans, Simon Newcomb and Alexander Agassiz. A further honor came to Dr. Hale when upon his resignation as chairman of the National Research Council, the title of honorary chairman was created and bestowed upon him in perpetuity by the Council in recognition of his distinguished service which contributed so largely to the organization of science for the assistance of the government during the war.

Walter Gould Davis.—By the death of Walter G. Davis on April 30th the world lost one of its most eminent and highly respected meteorologists. Beginning his scientific career in 1876 as one of the little group of brilliant assistants of the late Dr. Benjamin A. Gould at the Astronomical Observatory in Cordoba, Mr. Davis became, upon Dr. Gould's departure from Argentina, director of the meteorological service, a position which he filled with distinction for thirty years (1885-1915). It was largely thru his skill as a scientist and administrator that this department attained its present position in the very front rank of meteorological organizations. A keen, active and progressive director, Mr. Davis was also a man of wide learning and of a great variety of interests. The excellent meteorological and climatological publications of the Argentine Bureau issued under his direction constitute an inspiring record of splendid work and form a fitting monument to his memory.

Mr. Davis' successor, the present director of the Argentine Meteorological Office, Mr. George O. Wiggin, is also a native of the United States and was for ten years a member of the astronomical staff of the Cordoba Observatory.

Total Eclipse of the Sun, May 29, 1919.—Reports from the different expeditions sent out to observe the total eclipse of the Sun on May 29th, indicate that successful observations were obtained by at least two or three stations.

The two English expeditions expected to devote all of their efforts to the photographing of stars immediately surrounding the Sun, for the purpose of testing Einstein's relativity theory and also the hypothesis that light radiations are subject to gravitational action. From the station at Prince's Island, off the coast of West Africa, occupied by Professor Eddington and Mr. Cottingham, the brief message "Through cloud, hopeful" has been received. It probably signifies partial success in their observations. Dr. Crommelin and Mr. Davidson were located at Sobral in Brazil and appear to have had a clear sky for at least part of totality. Their photographs show all of the stars which they were hoping to obtain in the field around the Sun.

Magnetic observations were made at Cape Palmas, Liberia, by Dr. Bauer and party of the U. S. Magnetic Survey. Recent information from them states that the magnetic effect observed at previous eclipses has been confirmed by their results on May 29th. They also describe the inner corona as very bright with marked outer coronal extensions south southeast and north northwest of the Sun. No shadow bands were seen. J. H. M.

The Ultra Violet Band of Ammonia and Its Occurrence in the Solar Spectrum (*A Review*).—In the *Philosophical Transactions* of the Royal Society of London, Vol. 218, pp. 351-372, Messrs. A. Fowler and C. C. L. Gregory give the results of investigations on the ultra-violet band of ammonia and its occurrence in the solar spectrum. Spectrograms of an electric arc between copper electrodes in an atmosphere of ammonia were obtained with a 10-foot concave grating. The ultra-violet band λ3360 is shown to have associated with it six series of lines, three occurring on each side of the center of the band and extending over a distance of more than 70 A. The series on each side coalesce as they get farther from the center of the band. The central maximum at λ3360 is composed of fine lines which seem to form five series, two on the red side and three on the more refrangible side. The secondary maximum at λ3371 is composed of four series, of which three are on the red side and the fourth extends on each side of the center, thus giving the central maximum an unsymmetrical appearance. A comparison is made with the solar spectrum in this region. The central maximum is very strong in the Sun and the secondary maximum can also be seen. The comparison of individual lines measured within the solar spectrum is quite satisfactory. Of the 260 lines of ammonia in the region λ3450 to λ3286, about 140 coincide with previously unidentified faint lines in the solar spectrum. About 100 of the remaining lines are obscured by lines known to be due to other substances in the Sun. These investigations seem to establish with reasonable certainty the fact that the spectrum usually ascribed to ammonia is present as absorption in the Sun.

C. D. S.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN WHEELER HALL, BERKELEY, ON JULY 7, 1919, AT 8 P. M.

President Hodghead presided. By courtesy of the Dean of the Summer Session of the University of California, this meeting was scheduled as a feature of the summer course. It was also announced as the last of the lectures provided for by the Adolfo Stahl Lecture Fund.

Dr. George E. Hale, Director of the Mount Wilson Solar Observatory, delivered the address of the evening, having for his subject, "The Work of the Amateur Astronomer."

The address was beautifully illustrated and the speaker held the close attention of a large and very appreciative audience.

Adjourned. D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE FACULTY CLUB, IN BERKELEY, CALIFORNIA, ON JULY 7, 1919 AT 6:30 P. M.

On the suggestion of Director Aitken, this meeting took the form of a "business dinner," the members meeting about a well-supplied table at the Faculty Club.

There were present President Hodghead and Directors Aitken, Cushing, Costa, Roberts, Benfield, Galloway and Richardson. Dr. George E. Hale, director of the Mount Wilson Solar Observatory, was present by invitation.

The minutes of the previous meeting were approved as printed in the April issue of the PUBLICATIONS.

A communication was read from Mrs. Dorothea K. Roberts, in which that lady tendered her resignation as a member of the Board of Directors, stating as her reason a contemplated trip to Europe which will occupy several months. In the same communication Mrs. Roberts made application for Life Membership in the Society and enclosed her check for the customary dues.

On motion of Director Cushing, seconded by every one present, the resignation of Mrs. Roberts from the Board was declined. She was then elected a Life Member of the Society by unanimous vote.

Mr. L. E. Knowles was elected an Active Member of the Society.

Director Galloway, in a verbal statement to the Board, tendered his resignation as a Director, and same was accepted, coupled with an expression of appreciation on the part of the Board for services rendered.

On motion of Director Benfield, seconded by Director Aitken, Dr. George E. Hale was unanimously elected to fill the vacancy on the Board created by the resignation of Director Galloway.

A communication was read from Dr. W. W. Campbell in which that gentleman advocated the purchase by the Society of a lantern for its own use. After some discussion, the president was instructed to refer the matter to a committee of two who should make report, with such recommendations as they thought fit, at the next meeting of the Board.

President Hodghead appointed Dr. H. D. Curtis and Director Charles S. Cushing on this committee.

A further communication from Dr. Campbell was read by the secretary, in which the attention of the Board was invited to a consideration of the desirability of so amending the statutes for the bestowal of the Bruce Medal, that the number of nominating observatories might be increased from six to eight, or perhaps nine.

In view of the legal questions involved and the necessity of obtaining the consent of the heirs of Miss Bruce before making any changes in the original deed of trust, the lawyers present advised that consideration of the matter be deferred until the next meeting. A committee consisting of President Hodghead and Director Cushing was, in the mean time, instructed by the Board to take the subject under advisement and report at the next meeting.

Director Aitken, in a verbal statement, reported the completion of his work as editor and compiler of the "Adolfo Stahl Lectures in Astronomy," and announced that he had kept all expenditures within the gift allowance. He announced that the book is now ready for distribution.

A vote of thanks was extended to Dr. Aitken for his able and conscientious labors in the preparation of this valuable volume.

The Board then adjourned to attend the lecture of Dr. Geo. E. Hale in Wheeler Hall.

D. S. Richardson.
Secretary.

OFFICERS OF THE SOCIETY.

BEVERLY L. HODGHEAD	*President*
R. G. AITKEN	*First Vice-President*
MRS. ISAAC ROBERTS	*Second Vice-President*
J. COSTA	*Third Vice-President*
D. S. RICHARDSON	*Secretary and Treasurer*

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Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
Finance Committee—C. S. CUSHING, W. H. CROCKER, A. H. MARKWART.
Library Committee—D. S. RICHARDSON, F. V. CORNISH, MRS. ISAAC ROBERTS.
Donohoe Comet-Medal Committee—W. W. CAMPBELL, JOSEPH H. MOORE, STURLA EINARSSON.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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THE ADOLFO STAHL LECTURES IN ASTRONOMY

This volume contains the twelve Adolfo Stahl Lectures which were delivered in San Francisco in the seasons 1916-17 and 1917-18 under the auspices of the Astronomical Society of the Pacific by members of the staffs of the Lick Observatory, the Mount Wilson Solar Observatory, and the Students Observatory at Berkeley. They cover a wide range of topics, the endeavor being to present in non-technical language, but without sensationalism, some of the more recent results of studies of the Sun, the Moon, the Comets, the Solar System in general, the Stars and the Nebulae. One lecture, also, treats of the methods of astronomical discovery; another of recent progress in the study of motions in the solar system; still another, of the important epochs in the development of astronomy; and the volume concludes with a description of the great 100-Inch Reflector on Mount Wilson, the most powerful telescope in the world.

The volume is well illustrated. There are fifty-four full-page plates and twenty-four figures in the text. Altho the illustrations were selected primarily with reference to the text, they include some which are of historic interest and others which present some of the most recent developments of astronomy. For example, we have Keeler's beautiful drawing of Saturn made on January 7, 1888, the night on which the first successful observations were secured with the 36-inch refractor of the Lick Observatory, and the recent photographs of Jupiter, taken by Slipher at the Lowell Observatory, which are the finest ever made. Some of the stellar and nebular photographs, like the excellent one of the Pleiades by Dr. Isaac Roberts, in 1888, represent pioneer work in this field; others, like Barnard's photograph of the Milky Way in Ophiuchus and the photograph of the Great Nebula in Andromeda showing the location of the Novae recently discovered in it at Mount Wilson are typical of the best work with modern telescopes. On one page we find a photograph of the first reflecting telescope, the historic one-inch invented by Sir Isaac Newton; on other pages, views of the 72-inch reflector at Victoria and the 100-inch reflector at Mount Wilson.

It is, of course, impossible to cover the entire field of astronomical research in a series of twelve lectures; but the topics discussed are representative of modern astronomical work, and the book will introduce the reader to the point of view from which the astronomer of today regards the problems presented to him.

The volume has been printed for the Society at the Stanford University Press and is ready for distribution. The price of the book, substantially bound in cloth, is $2.75, postage paid. Orders should be sent to Mr. D. S. Richardson, 128 Lick Building, 35 Montgomery Street, San Francisco, Cal.

Mr. Stahl has generously provided that the proceeds of the sale of the volume shall go to the Society to form a special fund.

ASTRONOMICAL SOCIETY OF THE PACIFIC.

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THE INTERNATIONAL RESEARCH COUNCIL AND THE INTERNATIONAL ASTRONOMICAL UNION

By W. W. Campbell

The search for the truth in the leading departments of knowledge, especially in the domain of fundamental science, and chiefly in astronomy, has made desirable and necessary many international societies or committees for coöperation in research. These organizations reached considerable numbers late in the nineteenth century and early in the twentieth. In astronomy, for example, there were the Astronomische Gesellschaft, the Committee on the Carte du Ciel, the International Union for Coöperation in Solar Research, the International Geodetic Association, and many somewhat similar but less formally constituted bodies or committees dealing with transit of *Venus* phenomena, with celestial photography, with the fundamental determination of star positions, with astronomical ephemerides, with the reform of the calendar, etc.

In the sciences other than astronomy and seismology, international organizations for coöperation in research have been relatively few, but the usefulness of such bodies of investigators has been abundantly established.

The war of 1914-18, brought on by the governments of Germany and Austria-Hungary—with the sympathy and support of their subjects—and the inhumanity and barbarity with which the war was conducted, destroyed the usefulness of nearly all of the international organizations referred to. The scientists of the allied and associated nations were unable to subscribe to the Prussian view that *might* is *right* in international relations, and, with very few exceptions, they were of the opinion that personal relationships with the scientists of the central nations should not be resumed[1], at least until the offending governments and peoples shall have renounced their past, and apparently present, political methods. It should not be overlooked or forgotten that most investigators in pure science in the central nations are officials of their governments as truly as are their diplomats, their soldiers, and their sailors. The great majority of German professors, for example, were appointed, promoted, and in case of necessity disciplined, by their Kultus Ministerium, a definite department of their government.

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[1] "Inasmuch as the San Francisco *Chronicle* of September 27th misquoted and exaggerated my statement on this subject made to the faculty and students of the University of California on September 26th, it seems desirable to quote from the written address what I really did say on that occasion: "More than a year ago the scientists of France unanimously declared that they would take no part in scientific associations which should include the German scientists, at least until 'the central nations shall have repudiated the international political methods which have roused

In order to study the questions arising from the unfortunate international situation and to seek a practicable solution, there met in London in October, 1918, under the auspices of the Royal Society, thirty-six delegates representing the national academies or other similar societies of nine allied and associated governments. In brief, it was unanimously decided to withdraw from the very few international societies concerned, in accordance with the statutes or rules peculiar to each case, and to form new associations. A formal statement of the reasons which governed this momentous decision, as prepared and unanimously adopted by the conference, was reprinted in these PUBLICATIONS, **30**, 332-3, 1918; it is worthy of a second reading. The conference appointed a commission to prepare a general plan for the proposed international organizations. This commission made progress at its meeting in Paris in November, 1918.

The American delegates to the London conference had proposed that all the affected organizations relating internationally to one and the same subject, to astronomy, for example, should be succeeded by a single society, so formulated as to serve the purposes of all the associations from which they should withdraw. This policy was adopted.

It was later decided that representatives of the various sciences should meet in Brussels in July, 1919, to create international unions representing many different sciences, and to complete the organization of the International Research Council, whose principal functions relate to the promotion of research in any and all of its

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the indignation of the civilized world.' This sentiment was widespread thruout the allied and associated nations. (See Declaration of Interallied London Conference, *C. R. Académie des Sciences* for October 21, 1918, and *Publ. A. S. P.*, XXX, 332-3, 1918.) Are any of us inclined to criticize the French decision? Let him whose war sufferings have equalled those of the French throw the first stone! I know of a few American and British scientists who say we should renew personal relationships with the scientists of the central nations as soon as peace shall have been concluded; just as if the terrible war had not occurred, just as if the central nations had inflicted a mere football game upon the allied nations. I have been unable to avoid noticing that, of these very few scientists who would immediately renew personal relations with the Germans, not one had a son who was in a German poison-gas attack!"

aspects in any membership country, and especially to the coördinating of the proposed unions representing the several sciences. Altho the Council would in form be the parent and higher organization, its real office would be to serve and not to rule.

The National Academy of Sciences in each country, or its nearest equivalent, was requested to arrange for the sending of delegates to the Brussels meeting. The American delegation was organized under the auspices of the National Research Council; acting for the Academy. The Council's procedure to this end was most interesting, and worthy of careful notice and appreciation. It was vitally concerned that the American delegations should be truly representative of their respective sciences in this country; in astronomy; for example, no investigator and no institution, if up to standard, should find the avenue to appropriate representation closed. The astronomical delegation would be chosen by a subsidiary organization known as the American Section of the (proposed) Astronomical Union, and the American Section, at least for the present occasion, would be constituted as follows:

5 members from the National Academy of Sciences,
18 members from the American Astronomical Society,
3 members from the American Mathematical Society,
3 members from the American Physical Society,
1 member from the U. S. Naval Observatory,
1 member from the U. S. Coast Survey.

The American Section thus constituted held its first meeting in the office of the National Research Council, Washington, D. C., on March 8, 1919. About twenty of the thirty-one members of the Section were present. Mr. W. W. Campbell was appointed permanent chairman of the Section, with Messrs. C. G. Abbot, E. W. Brown, Frank Schlesinger, and Joel Stebbins as the other members of the executive committee. The Section gave assent to the actions of the London Conference and formally approved the proposal that those nations which had been neutral thruout the war should be admitted into the International Astronomical Union on the conclusion of peace. The Section did not consider seriously or extensively the form of organization which would promise the greatest usefulness for the proposed Astronomical Union, but concerned itself largely with the technical work of the Union in which the American astronomers would be chiefly interested. The Executive Committee was instructed to appoint sub-committees of the American Section which should prepare reports upon nineteen prominent divisions of astronomical research, for presentation at a later meeting of the Section. The Brussels delegation was selected in part, and the Executive Committee was authorized to complete it.

The delegation was eventually composed as follows:

W. W. Campbell, Lick Observatory, Chairman; W. S. Adams, Mount Wilson Observatory; Benjamin Boss, Dudley Observatory, Albany; Major Philip Fox, Dearborn Observatory, Evanston, at that time with the American Expeditionary Forces in France; S. A. Mitchell, McCormick Observatory, Virginia; Frank Schlesinger, Allegheny Observatory, Pittsburgh; C. E. St. John, Mount Wilson Observatory; F. H. Seares, Mount Wilson Observatory; Joel Stebbins, University of Illinois, Secretary.

The American Section met again in the office of the National Research Council on June 23rd and 24th, to receive and act upon the reports of the nineteen sub-committees, to consider questions of policy, and to instruct the delegation which would represent the Section at Brussels. The reports of the sub-committees, presenting the aspects of their subjects which are now prominent in the minds of astronomers, and suggesting procedure for the immediate future, were of a high order of excellence, and the discussions, conducted with enthusiasm and frankness, were extremely interesting and valuable.

A joint meeting with the American Section of the proposed International Geophysical Union (Major Wm. Bowie, Chairman) was held on the afternoon of June 23rd.

Under the direct auspices of the National Research Council, the American delegation to the meetings of the International Research Council at Brussels was appointed, with W. W. Campbell as Chairman. Other members were the scientific attachés in the American Embassies at Paris, London, and Rome, and the chairman of the American delegations representing the sciences other than astronomy.

The delegation of astronomers, accompanied by Mrs. Campbell, sailed from New York on June 30th and reached London on July 7th. The next ten days were devoted profitably and with unusual pleasure to renewing old acquaintances and making many new ones, to learning of progress in astronomy and related sciences in Great Britain made during the war period, to discussing with our British colleagues the many problems coming up for consideration at the Brussels meeting, etc. The President and Council of the Royal Astronomical Society had most kindly cabled to Washington a request that the members of the American delegation attend and address a special meeting of the Society on the afternoon of July 11th. This invitation was accepted. At the meeting, under the presidency of Professor Fowler, each member of our astronomical delegation, and likewise Dr. L. A. Bauer of the Geophysical delegation, addressed the Society informally on the astronomical subject which at this time especially interested him. This meeting had been preceded by a reception in the rooms of the Society, which gave opportunity to meet many British men and women whose names had long been familiar. Last, but far from least, the Royal Astronomical Society Club entertained the Americans in attendance at a dinner immediately following the meeting of the Society. The dinner was delightfully presided over by Professor Glaisher of Trinity College, Cambridge, who was ably assisted in making the introductions by Messrs. Dyson, Turner, Newall, and others. All members of the American delegation responded to toasts.

The delegation was cordially received at luncheon in the celebrated Greenwich Tower Room by the Astronomer Royal and Lady Dyson, and it was apparent that we were constantly in their thoughts during our stay in England.

The Americans were graciously invited to spend the week-end with friends at Cambridge, Oxford, and elsewhere.

Opportunities to observe the equipment and work of the Royal Observatory, of the observatories at Cambridge and Oxford, and of the laboratory of Professor Fowler in South Kensington were provided by members of their staffs.

In common with many British colleagues, the American delegation journeyed from London to Brussels on July 17th. The proceedings began on the following morning, at a meeting of the International Research Council, at which all delegates were present, with Albert, King of the Belgians, occupying the royal box. The opening of the session had been delayed a few minutes while the king, in an adjoining room, received the chairman of the delegation from each of the principal allied countries. The number of accredited delegates exceeded two hundred: one hundred and one from Belgium, two from Canada, twenty-seven from America, forty-five from France, eighteen from Great Britain, fifteen from Italy, one from New Zealand, one from Poland, two from Rumania, and two from Serbia.

Each week day from July 18th to July 28th inclusive was occupied with sessions of the International Research Council or of the affiliated organizations representing the individual sciences, together with meetings of executive and other committees. The work of the first seven days related chiefly to the construction and adoption of constitutions. The election of officers and the appointing of committees took place on the eighth and ninth days.

At the final session of the Research Council a formal invitation was extended to the scientists of the countries which had remained neutral in the war to participate in the work of the Council and of the international unions representing the several sciences.

Picard of France was elected president of the International Research Council, and Schuster of Great Britain was elected general secretary. Other elected members of the executive committee are Hale of America, Lecointe of Belgium, and Voltera of Italy. These five constitute the administrative Bureau of the Committee. The completion of the executive committee was held in abeyance until the more precise relationships of the Council and the affiliated unions shall have been determined. It is probable that the committee will consist of at least twelve members. The city of Brussels was selected as the legal home of the Council.

The most difficult question confronting the International Astronomical Union related to its composition. Should it be organized as a great astronomical society, comprehending all divisions of astronomical science in a somewhat general or indefinite manner, or should it consist of working committees, each committee concerned with some definite line of astronomical research? Should there, for example, be a great division of the Union relating to the solar system, or, on the contrary, several comparatively small committees occupying themselves respectively with such definite subjects as solar rotation, eclipses, solar radiation, etc.? The latter plan was adopted. To start with, thirty-two committees were established. These vary in size in accordance with the requirements and state of the problem concerned. The committee on the Carte du Ciel and the committee on Meridian Astronomy are relatively large, with more than a dozen members each, whereas other committees, such as those on Lunar Nomenclature, on Solar Radiation, on Astronomical Ephemerides, etc., are relatively small, with not more than half a dozen members each. The separate committees are working bodies. They are intended to be essentially complete in themselves. The Union as a whole will meet in general every three years in different educational centers of the world, but it is expected that the members of a given committee will find many occasions between general meetings when conferences by letter or otherwise may profitably occur. Committee reports will doubtless aim to represent the view of the committees as to the current status of their subjects, and to present suggestions for further undertakings. In other words, it is anticipated that each committee shall make known, thru its report presented at a general meeting of the Union, those aspects of its subject with which the workers in that subject can most profitably acquaint and busy themselves.

Each committee has power to add to its numbers, by favorable vote of two-thirds of the present membership of the committee, subject to approval by the Executive Committee of the Union.

It is provided in the Constitution that the committees shall automatically go out of existence at the close of each triennial meeting of the Union. This offers the opportunity for reorganizing upon the basis of those who work.

Monsieur Baillaud, Director of the Paris Observatory, was elected First President of the International Astronomical Union, and Professor Alfred Fowler, of South Kensington, London, General Secretary. Lecointe of Belgium, Ricco of Italy, Dyson of Great Britain, and Campbell of America, were selected as four of the five Vice-Presidents. The President, the Vice-Presidents, and the General Secretary compose the Executive Committee.

It was decided that the next meeting of the Astronomical Union should be held at Rome in 1922.

Certain of the working committees, such as those on eclipses, on time, etc., held meetings in Brussels promptly following their formation. It was deeply regretted that the work of organization was so time-consuming as to prevent nearly all of the committees from holding first meetings.

The earnestness and enthusiasm with which the work of organization was conducted, and the unanimity with which decisions were finally made, are the satisfactory indications that the Union will meet efficiently its purpose of promoting astronomical research, thru the coördinated efforts of the astronomers in many countries.

The Constitution of the International Astronomical Union will be published in this journal as soon as practicable following receipt of the official copy.

The International Geophysical Union, organized simultaneously by strong delegations from the larger countries, is composed of divisions concerned with seismology, vulcanology, terrestrial magnetism, the form and dimensions of the Earth, etc.

Other unions relate to chemistry, biology, physics, bibliography, etc.

All of the meetings were held in the splendid building of the Brussels Academy of Sciences.

The personal side of the Brussels meeting, as on all such occasions, was valuable. In addition to chance or informal groupings of delegates at the hotel where the greater number lived, there were delightful hospitalities in the homes of leading scientists of Brussels, and formal receptions by Mayor Max and the Council of Brussels and by Ministers of the Belgian State. A reception at the Royal Observatory by Director and Madame Lecointe should be specially mentioned. The members of the Observatory staff provided full opportunity for the large number of guests to see the many interesting features of the institution.

The two Sundays in Brussels were utilized by many delegates to visit Louvain, Dinant, and other places made famous by Kultur.

Following the work in Brussels, en route to London or Paris, several members of the American and British parties visited together the Bruges and Zeebrugge region, and the Ypres and Somme battlefields, under the splendid conductorship of Colonel F. J. M. Stratton, astronomer in the Cambridge Astrophysical Observatory, who had served more than four years in the thick of the war, chiefly in the Ypres and Somme areas. Not many visitors to the battlefields will be privileged to see them, as we saw them, by virtue of Stratton's enthusiasm and knowledge.

A few members of the American party went to Paris, where they were hospitably received by Director and Madame Baillaud of the Observatory, and others. Many interesting subjects engaged their attention at the Observatory, at the Eiffel Tower (under General Ferrié's enthusiastic and able leadership), at the Academy of Sciences, and at the Bureau of Longitudes.

It was, of course, not possible for us to forget, on any of our days in England, Belgium, and France, that our colleagues had but recently emerged from the dark valley of war; and we were constantly impressed by the courage and the dignity with which they had borne suffering and were now facing the problems of the future.

PRELIMINARY RESULTS OF A COMPARATIVE TEST OF THE 60-INCH AND 100-INCH TELESCOPES OF THE MOUNT WILSON OBSERVATORY

By George E. Hale

The close proximity on Mount Wilson of the 60-inch and 100-inch reflecting telescopes renders possible a comparative test of two similar instruments of large aperture. In order to make the results strictly comparable, the observations are preferably made simultaneously, and when these are photographic, the plates employed are taken from the same box and developed together for the same time. Other precautions necessary to eliminate sources of uncertainty are also observed.

The first simultaneous comparative tests of the series (which will be continued as opportunity offers thru several months) were made on August 13, 1919. The spectrum of the star ε *Andromedae* was photographed on Seed 30 plates with the two telescopes, using spectrographs having nearly identical optical constants, mounted at the Cassegrain focus.[1] For the 60-inch the equivalent focal length at this point is 80 feet, while for the 100-inch it is 134 feet. Both spectrographs have collimators of 2½ inches aperture and 40 inches focal length, and cameras of 4 inches aperture and 18 inches focal length. In each case a single 63° prism of 0.102 Jena glass is used, giving a dispersion of 36 angstroms to the millimeter with the camera employed. The slit-widths of the two spectrographs were varied until the photographic resolution determined by comparing close pairs of lines in the spectra of the same star, was found to be the same. The exposures on ε *Andromedae* were made by Dr. Strömberg with the 60-inch and by Dr. Merrill with the 100-inch, under good conditions of seeing.

Thirty-three spectrograms were secured for comparison. From twenty of these Dr. Strömberg finds the following mean ratios of exposure-times required to give the same intensities and photographic resolution with the two instruments:

Region............	$\lambda 4000$	$\lambda 4300$	$\lambda 4500$
Mean ratio........	4.5	3.2	3.3

As the light undergoes three reflections in each telescope, and as the small mirrors cut out nearly the same proportion of light in both cases, the theoretical ratio of exposure times would be $\left(\frac{100}{60}\right)^2 = 2.78$. The presence of the plane mirror in the optical train of the spectrograph of the 60-inch telescope, and the fact that the three mirrors of the 100-inch telescope have been more recently silvered than those of the 60-inch, probably accounts for the comparatively high value of the ratio at λ4000 (4.5), as the comparison spectra show no such change of relative intensity with wave-length. But these differences cannot affect the brightness at λ4500 by more than 15 per cent, judging from the constancy of the exposure times for stars of a given magnitude required with the 60-inch thruout the dry summer season. Another comparison will be made after the mirrors of the 60-inch have been resilvered.

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[1] The spectrograph of the 60-inch telescope contains a single plane mirror, not duplicated in the spectrograph of the 100-inch telescope.

A second comparative test, not based upon simultaneous exposures, is afforded by Dr. Merrill's experience with the stars of Class Md. Two hundred and one of these interesting objects, brighter than 9.0 magnitude at maximum, are known north of −30°. With the 60-inch nearly all of these stars can be observed for the bright lines with exposures not exceeding two hours. For the great majority, however, exposures of five hours or more are required with this telescope to yield a measurable absorption spectrum with the spectrographs already mentioned. In fact, so few stars can be effectively observed for both dark and bright lines that it would be hardly advisable to enter upon an extensive study of these objects with the 60-inch.

The greater light-gathering power of the 100-inch, however, renders such a study perfectly feasible. With this telescope, using the spectrograph mentioned above at the 134 foot Cassegrain focus, Dr. Merrill has obtained good photographs of the absorption spectrum (up to Hγ) of RY *Herculis*, 8.8 visual magnitude, in two hours, and of brighter stars of the same class with shorter exposures.

Dr. Shapley, who is continuing his investigation of star clusters with the 100-inch telescope, finds a similar gain of about one magnitude. With the small slitless spectrograph[2] mounted on the double-slide plate-holder at the 134-foot focus of the 100-inch, the exposure times for stars in the globular cluster Messier 11 are about as follows:

Photographic magnitude	Exposure
12	5 minutes
13	15 minutes

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[2] This spectrograph has a collimator of 18 inches focal length, a 39° prism of 0.102 glass, and a camera of 3 inches focal length. The scale is Hγ−K = 0.9 mm.

A further advantage results from the greater scale of the cluster in this focus of the 100-inch, which permits the spectra of stars that overlap in the corresponding focus of the 60-inch to be photographed separately. The important results obtained by Dr. Shapley in photographing the spectra of cluster stars down to the sixteenth magnitude, with an exposure of about one hour at the 134-foot focus of the Hooker telescope, are described elsewhere in this number of the PUBLICATIONS. In this work a single prism of small angle was mounted a short distance in front of the plate.

Excellent direct photographs of the central part of Messier 13 have been made by Mr. Pease at the 134-foot focus. The large scale of these photographs will permit the magnitudes of the less crowded stars to be determined without so much difficulty from the Eberhard effect as has been experienced with the 60-inch. Photographs of the Moon of superb definition have also been obtained by Mr. Pease at the 134-foot focus of the Hooker telescope. Some of these will be reproduced in a future number of these PUBLICATIONS. The extraordinarily minute detail on the Moon that I have repeatedly seen with the Hooker telescope affords a most satisfactory indication of its qualities.

Campbell's star with hydrogen atmosphere (BD+30°3639) is a beautiful object with the 100-inch telescope. An account of the preliminary results of photographic and spectrographic observations by Mr. Pease of this star at the 134-foot focus may be found on page 276.

One of the most interesting results yet obtained with the Hooker telescope is due to Professor A. A. Michelson, who spent the evening of September 18th on Mount Wilson. Some years ago, by placing two movable slits in front of the objective of the 12-inch telescope of the Lick Observatory, he was able to measure the diameters of *Jupiter's* four satellites by determining the visibility of the interference fringes. The same method, if used with a telescope of sufficient aperture, should permit the angular diameter of a star to be measured. It was a question, however, whether the fringes could be seen with very large apertures. After making satisfactory preliminary tests with the 40-inch Yerkes refractor, Professor Michelson applied the same method to *Altair* with the 60-inch and 100-inch telescopes on Mount Wilson. The fringes were beautifully seen with the full aperture of the 100-inch, on a night when the seeing was only 2 to 3 on a scale of 10. It is thus probable that an interferometer of the necessary dimensions, permitting the mirrors to be placed as much as 25 feet apart, could be successfully used at Mount Wilson on the best nights. An instrument of this size is being designed by Professor Michelson to be carried on the mounting of the Hooker telescope. Meanwhile the 100-inch mirror, as used in the interference observations of *Altair*, will also be applied to the measurement of very close double stars and the diameters of the nuclei of novae and planetary nebulae. The surprising sharpness and steadiness of the fringes, as seen under a power of about two thousand, affords solid ground for the belief that this method will prove of great importance in future work.

ON THE EXISTENCE OF EXTERNAL GALAXIES

By Harlow Shapley

I. Introduction

In the present state of astrophysical knowledge, the problem of the existence of external stellar systems similar to our Galaxy reduces almost immediately to the problem of the status of spiral nebulae in the sidereal universe. In treating this question we must deal primarily with the "island-universe" hypothesis of spirals—an interpretation of long standing, which at the present time has many adherents and appears to be growing in general acceptance.[1]

The recent work on star clusters, in so far as it throws some light on the probable extent and structure of the galactic system, justifies a brief reconsideration of the question of external galaxies, and apparently leads to the rejection of the hypothesis that spiral nebulae should be interpreted as separate stellar systems. During the last two or three years a considerable amount of observational material bearing on the problem has come to hand, much of which was either not known or not fully considered by previous writers on the subject.

Four classes of objects, other than spiral and closely associated nebulae, have at times been suggested as possible external galaxies, the first three of which may be dismissed as no longer open to such interpretation: (1) *Large star clouds of the Milky Way:* the affiliation with the galactic region and its characteristic population shows them to be a fundamental part of the galactic system; (2) *The Magellanic Clouds:* the apparent magnitudes of their short-period variable stars determine definitely the order of the distance and size of these detached stellar systems, and prove them to be small in comparison with the galactic system;[2] (3) *Globular clusters:* those so far discovered are recognized now as dependents of the galactic system, altho in many respects they are miniatures of the Galaxy and apparently for the most part are external to the regions where most of the galactic stars are found; (4) *Various peculiar nebulae*

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[1] Among special discussions of the theory, three should be mentioned: an article by Puiseux, "Spiral Nebulae," *Revue Scientifique*, April 6, 1912; Crommelin's paper "Are the Spiral Nebulae External Galaxies?" *Scientia*, v. 21, p. 365, 1917 (reprinted in the *Journal of the Royal Astronomical Society of Canada*, v. 12, 33, 1918); and the recent address by Curtis, "Modern Theories of Spiral Nebulae," *Journal of the Washington Academy of Sciences*, v. 9, 217, 1919. In all of these the evidence is held to be favorable to the "island universe" theory. The arguments reviewed and extended by Curtis are so fully and clearly expressed that they may be taken as presenting the case for the stellar interpretation of spiral nebulae. The alternative theory that the spirals are not stellar has been maintained little, if at all, in recent years.

[2] *Mt. Wilson Contr.*, No. 151, pp. 20 and 25, 1917; No. 152, p. 2, 1917.

and nebulous stars: concerning them little is known, but in most cases they are to be classed with the ordinary gaseous nebulae (which are clearly associated with the Milky Way), or with peculiar types of individual stars, or with the faint spirals.

II. OUTLINE OF EVIDENCE BEARING ON THE "ISLAND UNIVERSE" HYPOTHESIS

The relation of the spirals to the galactic system is not so easily disposed of as the cases considered above. In support or in partial support of the hypothesis that spirals are external stellar systems, arguments based on the following four points may be advanced:

(*a*) Distribution with respect to the galactic plane, assuming obstruction of light in and near the Milky Way.[3]

(*b*) High radial velocities.

(*c*) Certain spectral characteristics.

(*d*) Some evidences of great distance.

Less definite propositions that may be ranged on this side of the question are:

(*e*) Improbability of a single galactic system in the sidereal universe.

(*f*) Physical appearance of a few of the spirals.

(*g*) Resemblance of structure in spirals to hypothetical spiral structure of the Milky Way System.

In the light of recent studies of nebulae and the galactic system, the arguments founded on the seven foregoing points do not appear to establish the stellar interpretation; and none of them appears to be particularly troublesome for the hypothesis that the spiral nebulae are not external stellar systems. Many of these arguments, in fact, are better interpreted according to this alternative theory that spiral nebulae are truly nebular objects.

Five additional points, which are apparently of much weight and, taken together, seem decidedly unfavorable to the stellar interpretation of spirals, are as follows:

(*h*) New conception of the dimensions of the galactic system.

(*i*) Measures of internal motion in spiral nebulae.

(*j*) The occurrence of novae in spirals and their magnitudes at maximum.

(*k*) The systematic nature of the radial motions of spirals.

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[3] *Cf.* Curtis, *loc. cit.*, p. 225.

(*l*) The probable dependence of their distribution on galactic position.

Some of the foregoing are not completely independent of each other.[4] Four further points of less weight that may be suggested as opposed to the "island universe" theory are:

(*m*) The possibility of formulating a fairly satisfactory nebular theory of the spirals.

(*n*) Directly measured parallaxes.[5]

(*o*) The data of proper motion relative to mean distances and drifts.

(*p*) The apparent absence of a central nucleus in the galactic system.

III. REMARKS ON THE PRINCIPAL POINTS FAVORING THE "ISLAND UNIVERSE" HYPOTHESIS

a and *l*. The well-known avoidance of low galactic latitude by spiral nebulae, and the progressive but irregular concentration to the galactic poles, is most naturally taken as evidence that the distribution of spirals and galactic stars is to a certain extent complementary; therefore, that the spirals are dependent and subordinate factors of the general system. It would be difficult indeed to believe that external and independent stellar "universes" could exhibit such striking relations to our particular stellar system when, in addition to this apparent dependence of distribution on galactic latitude, we also note: first, that the avoidance by spirals (particularly by the brighter ones) is greatest in the direction of the galactic center where the stars, globular clusters, planetary nebulae, etc., are most numerous, and that the avoidance is least in the northern hemisphere where the Milky Way is the thinnest and globular clusters are totally absent; and, second, that the radial velocities observed are not random, but have a definite relation to the galactic system and perhaps even depend on the angular distance from an apical point in or near the Milky Way.[6]

On the other hand, Campbell,[7] Curtis,[8] and others have proposed that spirals may actually be distributed at random, and that the apparent distribution with respect to the Galaxy can be explained by assuming that obstructing matter encircles the galactic discoid —dark occulting nebulosity analogous to that observed in the peripheral equatorial regions of many spiral nebulae. Patches of dark nebulosity certainly exist in the galactic system, at no great distance from the Sun, and it is quite possible that the apparent avoidance of the lowest latitudes by globular clusters is due to such material.[9] Spirals in the galactic plane beyond the confines of our system would be occulted as readily as globular clusters. In general, the observed distribution could be secured by liberal use of the hypothetical encircling opaque material.

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[4] For instance, the value of *j* may involve a partial acceptance of *h*.

[5] van Maanen, *Mt. Wilson Contr.*, No. 158, 1918.

[6] *Mt. Wilson Contr.*, No. 161, Section VII, 1918. *Cf.* also reference below to work by Wirtz.

[7] *Science, N. S.*, **45**, 531, 1917.

[8] *Loc. cit.*

The region avoided by spirals, however, particularly in the southern hemisphere, is many times wider than that avoided by globular clusters. A great area of the southern sky (well out of the Milky Way[10]) is quite transparent both to near and to extremely distant globular clusters, but it is practically devoid of spiral nebulae sufficiently bright to have been observed. We must conclude, it appears, either that the spirals, whether near or distant, do not exist in that direction, or that there is a most remarkable arrangement of obscuring patches that eliminates all spirals but leaves a normal distribution of globular clusters.[11]

b. A few years ago Slipher's discovery that spiral nebulae as a class have extraordinarily high radial velocities gave new life to the theory that these objects are distant stellar systems.[12] The average motion of the various types of stars and nebulae has been contrasted many times and the argument advanced that, since all galactic objects have reasonably small velocities, these peculiarly high values should therefore be attributed to separate "universes." During the last few years, however, this supposed isolation of the spirals has been altered. While their average radial velocity exceeds 500 km/sec, it is less than 400 km/sec for one-third of them. A number of galactic stars are now known with space velocities equal to or in excess of 400 km/sec. With the extension of the investigations of proper motion and radial velocity to the fainter magnitudes many high stellar velocities are being found.[13] Many globular clusters,[14] which are certainly subordinate to the galactic system, have radial velocities between 100 and 300 km/sec, and the great Magellanic clouds[15] also appear to have very high velocities of recession. Hence this argument of peculiarity in velocity seems no longer an important one for the "island universe" theory. High speed is not a condition impossible of production by the forces inherent in our galactic system.

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[9] Shapley, *Proceedings of the National Academy of Sciences*, **5**, 344, 1919.

[10] Between galactic latitudes $+5^\circ$ and $+25^\circ$, -5° and -25°.

[11] A third explanation that spirals, as compared with globular clusters, are very near to the solar system cannot be accepted in the face of other evidences of distance.

[12] That the large line-displacements in the spectra of spiral nebulae should be attributed to motion in the line of sight appears to be assured by a consideration of the following points: (1) The displacements are both positive and negative; (2) The appropriate relation of shift to wave-length is observed; (3) Orbital motions in eclipsing binaries occasionally show displacements of the same order of magnitude; (4) In linear velocity the rotation observed spectroscopically in some spirals approaches the velocity in the line of sight.

c. The integrated and nuclear spectra of spirals are predominantly of a stellar type—usually resembling class G or K. With small dispersion the composite spectrum of a mixed group of stars, such as a globular cluster or a galactic system, would appear much the same. On the other hand bright lines are also found occasionally, and Seares's preliminary work on the distribution of color would indicate a much bluer spectral type for the nebular condensations in a spiral than for the nucleus.[16]

The analogy of the absorption spectrum of spirals with the composite spectrum of a stellar system cannot be carried very far, however, until higher dispersion has been used. We should remember that for many years stars differing so enormously in density, volume, and mass as the giant and dwarf eclipsing binaries of type G were classed together without question. Sidereal bodies in extremely different physical states obviously may give closely comparable spectra on the small dispersion that has been used for spiral nebulae.

d and *f*. With one or two possible exceptions the secondary nuclei in spiral nebulae are so distinctly nebulous that they cannot be considered individual stars. Even in Messier 33, probably the most conspicuously nucleated of the brighter spirals, it is easy on large-scale plates to distinguish between the superposed stellar images and the "softer" nebular condensations. It is possible, however, to see a resemblance of these diffuse nebulous objects to extremely distant stellar clusters,[17] but unless we introduce further unverified assumptions the analogy breaks down when the observed colors are intercompared.

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[13] Adams and Joy, *Mt. Wilson Contr.*, No. 163, 1919; *cf.* Wolf's frequent notes on large proper motions in recent volumes of the *Astronomische Nachrichten*.

[14] *Mt. Wilson Contr.*, No. 157, p. 12, 1918.

[15] R. E. Wilson, *Proc. Nat. Acad. Sci.*, **1**, 183, 1915.

[16] *Mt. Wilson Communication*, No. 36, 1916.

[17] *Publications Astr. Soc. Pac.*, **29**, 217, 1917.

IV. EVIDENCE UNFAVORABLE TO THE "ISLAND UNIVERSE" HYPOTHESIS

The observational and theoretical evidence against the stellar interpretation of spiral nebulae has already been discussed in various earlier papers on clusters;[18] in the present article space will be taken for only a brief summary of the arguments.

h. Formerly we compared any hypothetical external galaxy with a stellar system supposedly about 10,000 or 20,000 light-years in diameter. Recent studies of the galactic system indicate that its greatest diameter is not less than 300,000 light-years. This newer conception greatly embarrasses the interpretation of spirals as stellar organizations of a size comparable to that of the Galaxy. To be linearly as great as this, tho angularly small, demands a distance from the Earth, even for the spirals of largest angular size, that would completely discredit many observational results. For example, if any bright spiral of 10′ greatest apparent diameter has an actual diameter directly comparable with that of the galactic system, its distance must be greater than a hundred million light-years.

i. Under such circumstances the measures of internal motion by van Maanen, Kostinsky, and Lampland, would need to be summarily rejected. For instance, van Maanen's[19] careful measures of the nebulous points in Messier 101 would indicate rotational velocities greater than the velocity of light if that spiral is held to be even one-fifth as large as our Galaxy now appears to be. Similarly, the systematic drift derived by Wirtz[20] from a study of several hundred spirals, and the average proper motions suggested by the studies of Wirtz and Curtis[21] would indicate appalling velocities in space—quite irreconcilable with the spectroscopically measured velocities of translation and rotation.

j. Moreover, if in real dimensions spiral nebulae were analogous to our galactic system, the absolute magnitude of the novae in spirals would far transcend any luminosity with which we are acquainted, and would be at direct variance with present results on intrinsic stellar brightness. For at the distance computed above the absolute magnitude of a nova of the sixteenth apparent magnitude would be −16, nearly two hundred thousand times as bright as the novae of the galactic system for which van Maanen has determined the absolute luminosities.[22] An upper limit to the intrinsic brightness attainable by stars is suggested by recent observational and theoretical work, and this limit is much fainter than −16. The study of globular clusters, for example, has yielded sufficient knowledge of the luminosity of more than a million stars to show that not one is within ten magnitudes of this enormous brightness. The luminosity of about 2000 stars of the solar environs is now known, and probably none is even a ten-thousandth as luminous as absolute magnitude −16. Hence stellar luminosities of this order seem out of the question, and accordingly the close comparability of spirals containing such novae to our Galaxy appears inadmissible.

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[18] *Ibid.*, **30**, 42, 1918; *Mt. Wilson Contr.*, No. 157, p. 1, 1918, and No. 161, Sections VII and VIII, 1918.

[19] *Mt. Wilson Contr.*, No. 118, 1916.

[20] *Astronomische Nachrichten*, **203**, 197, 293, 1916; **204**, 23, 1917; **206**, 109, 1918.

[21] *Pub. Ast. Soc. Pac.*, **27**, 217, 1915. In subsequent references Curtis has stated his lack of confidence in the reality of the observed proper motions. *Jour. Wash. Acad. Sci.*, **9**, 221, 1919. The average time interval between first and second observations is 13 years and 40 years respectively, in the investigations by Curtis and by Wirtz.

Let us abandon the comparison with the Galaxy and assume an average distance for the brighter spirals[23] that will give a reasonable maximum absolute magnitude for the novae. Then the measured internal motions also become reasonable and in good agreement with spectroscopically determined rotational velocities; likewise the distances become reconcilable with the data from proper motion.

The simple hypothesis[24] that the novae in spirals represent the running down of ordinary galactic stars by the rapidly moving nebulosity becomes a possibility on this basis of distance, for the brighter spirals are within the edges of the galactic system. Further, it is possible to explain the peculiar distribution of spirals and their systematic recession by supposing them repelled in some manner from the galactic system, which appears to move as a whole thru a nebular field of indefinite extent.[25] But the possibility of these hypotheses is of course not proposed as competent evidence against the "island universe" theory.

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[22] *Cf. Pub. Ast. Soc. Pac.*, **31**, 234, 1919.

[23] Provisionally, let us say, of the order of 20,000 light-years. If novae in spirals attain apparent magnitude 16, certainly bright stars, if present, should be easily photographed, and the failure to resolve the brightest spirals indicates that they are not composed of typical stars. (*Cf.* a suggestion on the origin and constitution of spiral nebulae, *Mt. Wilson Contr.*, No. 161, p. 29, and also the mathematical theory by Jeans, *Monthly Notices*, **77**, 186, 1917). At a distance of 20,000 light-years, if there were ordinary stars of absolute magnitudes between 0 and +5, they would appear of magnitudes 14 to 19, and therefore conspicuous on ordinary photographs. Even if 200,000 light-years distant, the giant stars would be easily resolved on existing photographs.

[24] *Pub. Ast. Soc. Pac.*, **30**, 53, 1919.

[25] *Mt. Wilson Contr.*, No. 161, Sections VII and VIII, 1918.

V. CONCLUSIONS

Observation and discussion of the radial velocities, internal motions, and distribution of spiral nebulae, of the real and apparent brightness of novae, of the maximum luminosity of galactic and cluster stars, and finally of the dimensions of our own galactic system, all seem definitely to oppose the "island universe" hypothesis of the spiral nebulae. Data relating to proper motion are also in better harmony with the hypothesis that spiral nebulae are not stellar systems. The evidence now supporting the "island universe" interpretation appears unconvincing, for many of the best arguments formerly proposed on that side of the question have been invalidated or much weakened by recent research. We have, however, no evidence that somewhere in space there are not other galaxies; we can only conclude that the most distant sidereal organizations now recognized—globular clusters, Magellanic clouds, spiral nebulae—cannot successfully maintain their claims to galactic structure and dimensions.

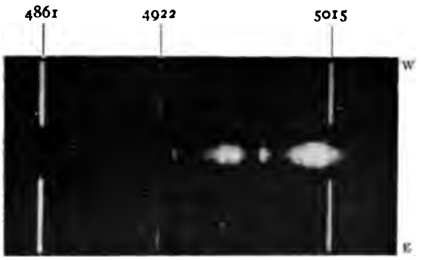

FIG. 1

Spectrogram of *Nova Aquilae*, August 1, 1919
Slit in position angle 112°

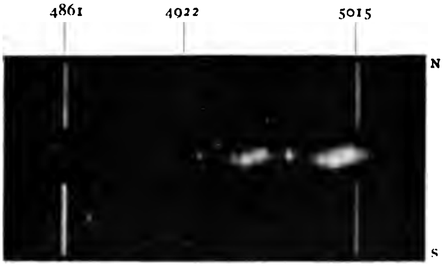

FIG. 2

Spectrogram of *Nova Aquilae*, August 1, 1919
Slit in position angle 202°

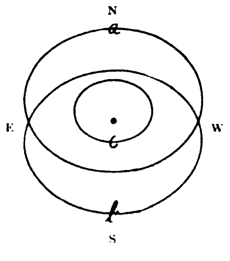

FIG. 3

a. *Nova* image in 5012 A.
b. *Nova* image in 5002 A.
c. *Nova* image in 4978 A.

PLATE IX.

THE GREEN NEBULAR BANDS IN NOVA AQUILAE No. 3

By J. H. Moore and C. D. Shane

During the months of July, August, and September we have secured a number of spectrograms of *Nova Aquilae* No. 3, with spectrographs of one-prism and three-prism dispersion attached to the 36-inch refractor. As the image of the nova is a small greenish disk about two inches in diameter, an opportunity was offered to test this object for evidences of internal motion and for varying distribution of emitted light. For this purpose it was necessary to hold the image of the nova fixed on the slit during the exposure instead of allowing it to drift along the slit as is usually done with the stellar objects. The first two spectrograms secured in this manner were obtained on July 22nd with one-prism spectrographs respectively in the visual and photographic regions. On both of these the nova bands N_1 and N_2, or those whose centers coincide approximately with the nebulium lines 5007A and 4959A, extend on either side of the narrow continuous spectrum at least twice as far as the bands at $H\alpha$, 5755, $H\beta$, 4660, 4363, $H\gamma$, and $H\delta$. Evidently the greenish nova disk is due chiefly to these two nebular bands. Unfortunately, on these two plates the form of the N_1 and N_2 bands was seriously affected by the chromatic aberration of the 36-inch objective. On the spectrogram taken with the visual spectrograph, N_1 and N_2 suffered much less from this disturbance, and on this plate the nebular bands have a peculiar form the real nature of which was clearly indicated by Professor Wright's observations secured a few nights later with a slitless spectrograph and the Crossley reflector.

Mr. Wright's observations, altho obtained with much lower dispersion than that used by us, enabled him to study this effect in all of the nova bands from 3346 to 5007A. The results of his interesting investigation have been described by him in *Lick Observatory Bulletin* No. 322. In this same number of the *Bulletin* we have given the results of our detailed study of the effect of the N_1 and N_2 nebular bands, as shown on our spectrograms obtained with one-prism dispersion. As our observations have been confined for the most part to N_1 and N_2, the slit was placed in the focus of the objective for rays of wave-length intermediate between those of the two nebular bands.

In Plate IX, figures (1) and (2), are reproduced two of our one-prism spectrograms (each 30 minutes exposure) of August 1, 1919, a comparison of which shows the peculiar form of the N_1 and N_2 bands, observed along two particular axes of the nova image at right angles to each other. The plate of figure (1) was secured with the slit across the nova image in position angle 112°. In this case the two bands present the general form and appearance of those observed in previous novae at this stage of their development and in particular in the present one as described by Messrs. Adams and Joy.[1] In figure (2), however, for which the slit was placed across the nova disk in position angle 202°, the two bands have a sinuous form which may be likened roughly to a capital S placed horizontally along the direction of the spectrum. These two plates represent respectively the minimum and maximum effects of the sinuous form. The directions in which the slit should be set across the nova image in order to obtain them were determined from Mr. Wright's slitless spectrograms and our plates taken with the slit placed in a number of position angles.

The vacuum tube spectra of hydrogen and helium were photographed on each plate for comparison. In the illustration the $H\beta$ (4861A) line of hydrogen and the two helium lines 4922A and 5015A are indicated. The two nebular bands N_1 (one on the right in illustration) and N_2 are some 50 or 60A in width and in consequence overlap slightly. As they are quite faint in the region where overlapping occurs they appear fairly well separated on plates of short exposure. They are quite similar in structure, but N_1 is much stronger than N_2. Each band consists of a strong central portion some 30A in width accompanied by outlying appendages, of which the most conspicuous is the strong narrow maximum situated 29A to the violet of the center of the band. The section whose width is about 30A shows a marked increase in intensity in its central portion some 10A in width, which in turn is divided into several maxima and minima.

We have recently obtained several spectrograms of the nova with a three-prism spectrograph set for minimum deviation in the region of the nebular bands. These show a still more complicated structure of the maxima and minima in N_1 and N_2 than those given by our one-prism plates. A detailed discussion of these results will be published later.

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[1] *Pub. Astr. Soc. Pac.*, **31**, 182, 1919.

The sum of measured distances to which the nova spectrum extends on each side of the center of the continuous spectrum, when reduced to seconds of arc by means of the known constants of the 36-inch telescope and spectrograph, gives the corresponding value of the diameter of the nova disk. From our measures we have subtracted the width of the continuous spectrum of the stellar nucleus in an effort to eliminate effects due to the chromatic aberration of the 36-inch lens, the astigmatism of the prisms, and the unavoidable drifting of the image on the slit. Owing to the faintness of the continuous spectrum on our plates, it appears probable that the effects of these sources of error have not been completely removed from our results.

The mean diameters of the nova disk as shown by our measures are as follows:

[1]N_1	3″.0	one-prism
	2″.6	three-prism
N_2	2″.2	one-prism
	1″.8	three-prism
$H\beta$	1″.0	one-prism

The measure of the $H\beta$ band was made on a spectrogram for which the slit was placed in the focus of the objective for the $H\beta$ rays. This spectrogram was obtained with the slit in position angle 202° and the $H\beta$ band shows the same form as that given by N_1 and N_2 in this position. Mr. Wright has shown that this same form characterizes all of the nova bands from 3346 to 5007A, but that the disks corresponding to the hydrogen radiations are only slightly larger than that of the central stellar nucleus.

The obvious interpretation of the form of the bands obtained in the various positions of the slit is that different wave-lengths have their origin in different parts of the nebula. Referring to the spectrogram obtained with slit along the axis in position angle 202°, figure 2, the strong maxima in N_1 at 5012A and 5002A have their origins respectively in the northern and southern portions of the disk. Similarly the origin of the portion of the band 5030-5040A, while in the central region of the nova, lies wholly south of the center of the disk. The maximum 4978A at the more refrangible edge of the N_1 band also originates in the central part of the disk, but in a region for the most part north of the stellar nucleus. In figure 3 we have drawn the approximate elliptical disks which are the sources of the radiations in the N_1 band at 5012, 5002, and 4978A, denoted respectively by the small letters *a*, *b*, and *c*. The source of the continuous spectrum is represented by the small dot at the center.

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[1] Mr. Wright, from his slitless plates obtained the mean diameter of the nova disk corresponding to N_1 and N_2 as 2″, and for 4363 a diameter of 1″.

An examination of our one-prism spectrograms and one obtained with three-prism dispersion (slit in position angle 146°) for evidence of inclination of the detailed structure of the bands, either the maxima or minima, failed to indicate the presence of such an effect on these plates. Spectrograms which we have obtained later with a three-prism spectrograph, and with the slit in position angle 112°, indicate, however, that the maxima and minima in the strong central section of the N_1 and N_2 (some 10A in width) show an average inclination of nearly 10° with respect to the zero direction as given by the comparison lines and in the sense that the portion of line originating in the western part of the nova is displaced toward the red. The inclination is not the same for all the maxima and minima, and in the outer portions of the band there are examples of no inclination and a few examples where the lines appear slightly inclined in the opposite direction. The phenomenon appears to be a very complex one. On the spectrograms obtained with the slit in position angle 202° or those on which the maximum sinuous effect is shown in the form of the bands, little or no inclination appears to be shown by the detailed structure. It is interesting to note that the maximum inclination of the internal structure of the bands is obtained when the slit is placed parallel to the major axes of the elliptical images drawn in figure 3. Altho this is the spectrographic effect to be expected from a rotating ellipsoid, the phenomenon may be due to some other cause.

Observations which we have secured for the purpose of testing for the presence of plane polarization in the portion of the bands originating at the north and south edges of the disk appear to be conclusive in showing that the observed form of N_1 and N_2 is not due to the presence of plane polarized light, but is a real effect in the nova itself.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1919

BY MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME

Full Moon	Nov.	7, 3^h35^m P.M.	Full Moon	Dec.	7, $2^h\ 3^m$ A.M.
Last Quarter	"	14, 7 40 A.M.	Last Quarter	"	13, 10 2 P.M.
New Moon	"	22, 7 20 A.M.	New Moon	"	22, 2 55 A.M.
First Quarter	"	30, 8 47 A.M.	First Quarter	"	29, 9 25 P.M.

The second eclipse of the year is a *Partial Eclipse of the Moon* on November 7th. The beginning is visible in Europe, Africa, the eastern part of North America and South America except the extreme western part; the ending is visible generally in Europe, Africa, South America, and North America except the extreme western part. The magnitude of the eclipse is small, less than one-fifth of the Moon's diameter being obscured when the eclipse is at its maximum.

The principal phases occur as follows:

Moon enters penumbra	Nov. 7, 1^h34^m P. M. Pacific Time
Moon enters umbra	Nov. 7, 2 58 P. M. Pacific Time
Middle of eclipse	Nov. 7, 3 44 P. M. Pacific Time
Moon leaves umbra	Nov. 7, 4 30 P. M. Pacific Time
Moon leaves penumbra	Nov. 7, 5 55 P. M. Pacific Time

The third eclipse of the year is an *Annular Eclipse of the Sun* on November 27th. The path of the annulus runs from Texas thru the Gulf of Mexico, Cuba, nearly down to the north coast of South America, thence across the Atlantic into Africa, ending not far from Timbuktu. It may be seen as a partial eclipse thruout the greater part of North America and western Europe. The conditions governing the relative sizes of the Sun and Moon are reversed from those at the May eclipse; the Moon is in apogee, hence of smallest apparent size, and the Sun is nearly at its least distance from the Earth, hence nearly the greatest apparent size, and the Moon is too small to cover the whole disk at once.

The winter solstice, the time when the Sun reaches its greatest distance south of the equator, occurs December 22nd, 1^h27^m P. M. Pacific Time.

Mercury on November 1st is an evening star setting not quite an hour after sunset, therefore not in good position for observation. The apparent distance from the Sun increases and greatest east elongation occurs on November 12th. The planet then sets rather more than an hour after sunset; so that for a few days before and after this date it may be seen in the evening twilight. After greatest east elongation the distance between planet and Sun diminishes rapidly, inferior conjunction being passed on December 2nd, the planet becoming a morning star, rapidly increasing its distance from the Sun. By the middle of the month the planet rises about an hour and three-quarters before sunrise and the interval does not fall below an hour and a half thru the rest of the month. Greatest west elongation is reached on December 21st. The last half of December is therefore an excellent time for observations in the morning twilight.

Venus is a morning star, rising nearly four hours before sunrise on November 1st. During the latter half of the month the interval is more than four hours. During December it slowly diminishes to about three and a half hours at the close of the month. Greatest west elongation occurs on November 23d. The planet passed its greatest brilliancy late in October but does not diminish greatly in brightness during the rest of the year. Its "stellar magnitude" diminishes from -4.3 late in October to -3.7 at the end of December, a loss of only half a magnitude. At its brightest it was more than fifty times as bright as the normal first magnitude star, and at the end of December it is still more than thirty times as bright.

Mars is still a morning star, gradually increasing its apparent distance from the Sun. On November 1st it rises a little before 2 A. M., and more than an hour earlier at the end of December. Its brightness is gradually increasing, being about twice as great in December as it was in June, and is a little fainter than the normal first magnitude star. It moves about 30° south and east from *Leo* into *Virgo* nearly on the line from *Regulus* to *Spica*.

Jupiter rises shortly before midnight on November 1st and at a little before 8 P. M. on December 31st. It is in the western part of *Leo* and moves slowly eastward about 2° up to December 5th. Its motion then reverses and during the rest of the year it moves about 1° westward.

Saturn is in the same quarter of the sky, rising about two hours later than *Jupiter*, at about 1:30 A. M. on November 1st, and at a little before 10 P. M. on December 31st. It is also in *Leo*, and moves about 2° east and south, being about 12° east and south of the principal star of the constellation *Regulus*. The apparent minor axis of the rings still continues to diminish, being only about one-twelfth of the major.

Uranus is well situated in the southwestern sky for evening observation, remaining above the horizon until after midnight on November 1st, and setting shortly before 9 P. M. on December 31st. It moves a little westward up to November 7th in the constellation *Aquarius*, then during the rest of the period it moves about 1° eastward. It is still in the neighborhood of the fourth magnitude star *Iota Aquarii* and early in December is about 1°25′ north of the star, being in almost the same position relative to the star as in early October.

Neptune remains in the constellation *Cancer* in the eastern sky in the evening, rising quite late.

NOTE ON THE DOUBLE STAR, HUSSEY 321,=BURNHAM'S GENERAL CATALOGUE No. 8629

By Eric Doolittle

This interesting, tho faint and wide, pair has the large motion in angle of more than 1° a year; the distance, also, has increased 2″.3 since its discovery twelve years ago. The complete measures to date are as follows:

1901.66	340°.1	4″.41	9.3	11.1	Hussey 3*n*	−0″.02
1910.16	350 .3	5 .63	9.3	11.1	Doolittle 3*n*	+0 .24
1910.53	351 .9	5 .40	9.1	10.7	Abetti 4*n*	−0 .05
1912.66	352 .0	5 .50	9.1	10.5	Fox 3*n*	+0 .01
1919.69	0 .0	6 .68	9.4	10.3	Doolittle 5-3*n*	−0 .04

With so few observations a least squares reduction is not desirable; by the graphical method, however, we find (assuming the motion to be rectilinear)—motion of A=0″.144 in 212°.2. The residuals in distance from this assumption are given in the above tabulation, and from these it will be seen that the observations are well represented. This is a large proper motion for so faint a star.

By the time this note can be published the star will be low in the west, but it should be occasionally observed when possible, as so large a motion in so faint a star is unusual. Its position for 1900.0 is R. A.=$18^h27^m32^s$; Decl.=+23°5′.7.

The Flower Observatory,
September 19, 1919.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE RING NEBULA B. D. +30° 3639

Since Campbell first discovered that the B. D. star +30° 3639 was enveloped in nebulosity, little has been said regarding the disk itself, altho much work has been done on its spectrum. With the large scale (1606 inches focal length) of the Cassegrain focus of the 100-inch reflector available, a number of direct photographs were taken, together with some slitless spectrograms, with focal-plane spectrograph III having camera and collimator of about 6 inches focus.

The data are as follows:

a 1919, Aug. 17, Direct, 45^{m}. Cramer Iso. Image elongated.
b 1919, Aug. 17, Direct, 5^{m} and 10^{m}. Bathed Seed 23 3 dye. Image small and nearly round.
c 1919, Aug. 17, Direct, 5^{s}, 15^{s}, 45^{s}, 135^{s}, and 8^{m}. Wratten M. Image elongated.
d 1919, Aug. 22, Slitless spectrogram. Iso. 1^{h}. Fair image.
e 1919. Aug. 26, Slitless spectrogram. Bathed Seed 23 3 dye. 2^{h}. Good image.
f 1919, Sept. 28, Slitless spectrogram. Iso. 2^{h}. Image large.

The 45-minute plate *a* is over-exposed, but shows an almost uniform disk, approximately round, save that there is a portion lacking in the Nf quadrant.

The 5-minute and 10-minute plate *b* shows the central star surrounded by a non-uniform disk having greatest intensity at several points around the periphery, notably a point a little preceding North and the whole Sf quadrant. This plate shows well the break in the Nf quadrant.

Plate *c* was taken to show the formation nearer the star and confirms everything on plate *b*.

The one-hour slitless spectrogram *d* is extremely interesting, as Hβ, Hγ, and Hδ, traces of Hε, and 3727 are rings repeating the general form of the direct photograph to a greater or less extent.[1]

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[1] Observations made by Mr. Wright with a slitless spectrograph in September, 1916, show this object to be a ring nebula. It is described as follows in *Lick Observatory Publications*, **18**, 221 the printing of which has been delayed by war conditions, but which is now in press:

"An excellent plate secured with the slitless spectrograph shows that the envelope, or nebula, is not a disc, but an exceedingly minute ring, irregularly elliptical in shape and somewhat eccentrically placed with respect to the bright star. The axes of the Hβ ring, in the sense mean of inner and outer diameters, are about 2″ and 3″ respectively. The spectrogram in question probably represents the limit of definition obtainable with this apparatus. It is reproduced in plate L, magnified about seventeen diameters from the original negative. The outer diameter of the image as measured on this plate is about 5″. An increase in exposure extends the borders slightly."

Mr. Wright's observations were made with the Crossley reflector and as the pictures are only an eighth of the size of those secured at Mt. Wilson the amount of detail is less.—Editor.

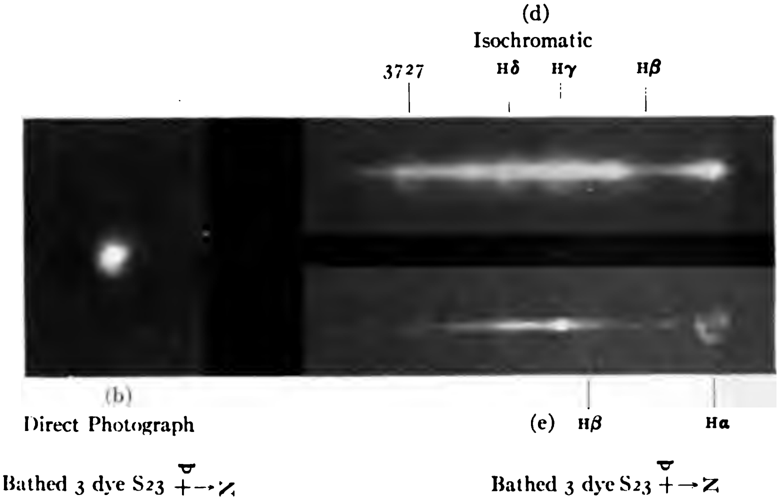

FIG. 1. The Ring Nebula B. D. + 30° 3639

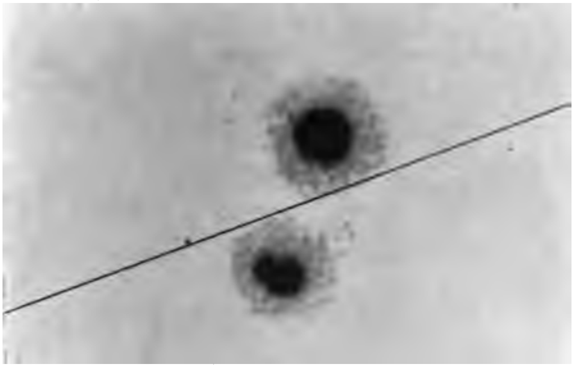

FIG. 2. Spots close to the Sun's Equator, September 13, 1919

PLATE X.

The two-hour slitless spectrogram *e* shows the Hα (group) and Hβ as rings in which the Np and Sf quadrants are stronger, as on the direct photographs.

The two-hour spectrogram *f* confirms everything on plate *d*.

FRANCIS G. PEASE.

Plates *a*, *d* and *e* are reproduced in Figure 1 of Plate X.

TWO SUN-SPOTS CLOSE TO THE SUN'S EQUATOR

During the last rotation of the Sun two spots have been present which were very unusual because of their positions close to, but on opposite sides of, the Sun's equator. These groups appeared on the east limb of the Sun in the afternoon of August 12th. The north group, which was then 6° from the equator, was a well developed stream with a large leader. The south group was but 3° from the equator and, judging by its subsequent growth, had been born but a few hours earlier, most likely on August 11th or 12th.

As the Sun's rotation carried the groups across the disk two interesting things happened. The leading spot of the south group grew rapidly, its diameter increasing about 2000 miles per day for ten days. At the same time the leader of the north group, which was already over 30,000 miles in diameter, drifted south at the rate of 4500 miles per day. By August 23rd the edges of both spots had reached the equator, the south one by expansion and the north one by drifting.

During the time from August 13th to August 24th these two groups offered fine examples of the bipolar type. All the spots in the preceding part of the north group, including the large leader, were of the same magnetic polarity as the Earth's south magnetic pole, while the spots in the following half of the group were like the Earth's north magnetic pole. In the south group, just across the equator, the magnetic conditions were exactly reversed.

As the groups approached the west limb the following spots grew smaller, so that when they reappeared at the eastern limb on September 10th it was not surprising to find that the two preceding spots were all that was left of the groups. Their relative positions had not changed during the two weeks in which they were out of sight nor did they change during the following days. By September 15th they began to show signs of breaking up, in a very normal manner, however.

In Plate X, figure 2 reproduces them as they appeared September 13th. The line drawn between them indicates the position of the Sun's equator. The north spot was then 30,000 miles in diameter, the south one 26,000 miles. The distance between their centers was 33,000 miles, leaving a space of but 5000 miles between the edges of their penumbras. The field-strength at the center of the north spot was 3200 gausses and at the center of the south spot 3000 gausses, but of opposite sign.

From the behavior of these spots it would seem as if there must have been some condition which prevented them from crossing the equator, otherwise one would have expected the two spots to drift together instead of the larger drifting toward the smaller. At any rate they illustrate remarkably the difference in polarity of sunspots on opposite sides of the Sun's equator.

SETH B. NICHOLSON.

NOTE ON A SENSITIVE SPECTROGRAPHIC ARRANGEMENT

The great light-gathering power of the 100-inch telescope, the freedom from chromatic aberration, the long focal length, and the consequent slow convergence of light at the secondary focus, make it possible to develop a simple and effective device for obtaining the spectral types and absolute magnitudes of extremely faint stars in crowded regions (such as globular or open clusters), as well as of faint isolated objects in general. The faintness to which our greatest instruments can carry spectroscopic researches is definitely limited so long as we demand sufficient dispersion and definition to permit extended analyses of lines in stellar spectra or desire to use spectroscopes largely for accurate determinations of radial velocity. This working limit can be considerably extended if we sacrifice dispersion and accuracy in radial velocity measures; and, if we are willing to forego altogether the velocities (uncertainly determined with one of these small-dispersion spectroscopes) and to aim at the derivation of spectral types alone, we may do away with the slit, which is generally very wasteful of light, and lower still farther the magnitude limit.

Recent experiment at the secondary focus of the 100-inch reflector with an especially rapid, slitless, focal-plane spectroscope gives in a five-minute exposure the spectral type of twelfth magnitude stars. In clusters, as many as thirty stars were photographed at one time, but the scale is reduced to one-sixth the original at that focus, with consequent confusion in dense regions. Notwithstanding the loss in dispersion and definition, on such plates most types show sufficiently clear absorption lines for spectral identification; there is little hope, however, of obtaining on such low dispersion absolute magnitudes from spectral lines. But the absorption lines are not the only criteria of spectral type and absolute luminosity, and in attempting to push as far as possible our knowledge of these properties in star clusters, it becomes evident that if we can so adjust our problem that the definition and dispersion necessary to retain spectral lines become unimportant, we may considerably extend the magnitude limit by eliminating some other light-wasting optical parts of the spectroscope.

The obvious solution of the problem is to do away with collimating and camera lenses altogether, and substitute for the thick, large-angled prism of the spectroscope a thin, small-angled prism, placing the latter not back of the focus of the telescope but in the slowly converging beam. With plates properly sensitized the spectrum may be photographed thruout the interval from less than 4000 A to greater than 7000 A, with a sharp break in the green, which affords a constant reference point and readily permits the comparison, visual or microphotometric, of the extent and intensities of the red and blue divisions.

With a prism of 6° angle and 12 inches clear aperture, mounted 20 inches in front of the plate-holder, preliminary photographs of the open cluster Messier 11 have been made with the 100-inch telescope. An exposure of 20 minutes on an ammoniated Wratten M plate gives the spectra of more than 250 stars with photographic magnitudes from 12 to 14. Seed 30 plates, dyed with pinacyanol, appear to be much faster, but the dividing segment may not be as efficient. The field satisfactorily covered is about 4.5 inches = $8'$ in radius. For stars of color index $+1.6$, the red division of the spectrum is about three times as intense as the blue; for stars of color index $+0.2$, the blue division is some five times as intense as the red.

Advantages of this spectroscopic arrangement are:

(1) It appears to be much faster than the most rapid focal-plane spectrograph now in use, and covers at least five times the angular field.

(2) It utilizes to full extent the scale of the 100-inch telescope, permitting close investigation of the centers of clusters.

(3) It requires the development of criteria for spectral type and absolute magnitude that make use of a much greater interval of wave-length and particularly of the neglected red end of stellar spectra.

(4) The relatively slower speed of photographic plates in the red is offset by the prismatic concentration, so that for G-type stars the two divisions are of comparable intensity.

(5) The small demands on definition permit the use of this arrangement during unfavorable conditions of seeing.

HARLOW SHAPLEY.

METCALF'S FIRST COMET

Metcalf's first comet was photographed September 15 with the 10-inch triplet at Mount Wilson. An exposure of one hour, from 7:14 to 8:14 P. S. T., showed the comet as a round nebulosity about 12 minutes of arc in diameter with a faint tail, three and a half or four degrees long, in position angle 22 degrees. The comet was much condensed toward the center but showed no stellar nucleus. The tail left the head as a very narrow ray which spread but little as it receded, reaching a width of about 6 minutes of arc at a distance of two and a half degrees. At this point it spread out abruptly on the northwest side to a width of 20 minutes near the extreme end. Half a degree from the head there was a faint ray about one degree long extending to the northwest, making an angle of about five degrees with the main tail.

SETH B. NICHOLSON,
MILTON HUMASON.

NOVAE IN THE ANDROMEDA NEBULA

No. 14, discovered by Miss Ritchie, 290″ east, 180″ south of nucleus, near edge of bright, soft nebulosity, appears on plates of 1919, July 21st and 23rd, by Shapley, and on those of July 28th and 29th, by Duncan.

ESTIMATED MAGNITUDES OF NO. 14

July 21	15.9
23	15.9
28	16.0
29	16.1
Aug. 24	>18.5 (invisible)

No. 15, discovered by Duncan, 160″ west, 170″ north of nucleus, about 1′ southwest of Nova No. 12, in large curdled area of the nebula, appears on plates of July 21st, 23rd, 28th, 29th. Novae 14 and 15 lie almost on the minor axis of the nebula, on opposite sides of the nucleus.

ESTIMATED MAGNITUDES OF NO. 15

July 21	17.2
23	17.0
28	17.3
29	17.5
Aug. 24	18.0

No. 16, discovered by Shapley, approximately 200″ west, 190″ south of nucleus, nearly superposed upon a nebulous spot of magnitude 18.5, appears first on a plate made by Benioff on August 1st at the secondary focus of the 60-inch, with estimated magnitude 17.1. It appears on subsequent plates by Duncan and Sanford. The nova was verified visually by Shapley August 2nd at the secondary focus of the 100-inch telescope—apparently the first visual record of a nova in the *Andromeda* nebula since No. 1 appeared in 1885.

HARLOW SHAPLEY,
J. C. DUNCAN.

THE COMETS OF 1919

After a prolonged period with no new comet discoveries, three comets have now been found, the last two within three days of each other.

The first comet of 1919 was found by Wolf at Heidelberg. It was not, however, an unexpected comet, for it was located with the assistance of a search ephemeris by Ebell. It was first seen in 1906, having then been discovered by Kopff, whose name is therefore attached to it. It was not very bright at that apparition, but it was observed quite well, and an accurate orbit was computed. It passed perihelion again in 1913, but was not seen, as it was in in the same region of the sky as the Sun.

This year it is much better situated, and has been observed repeatedly since its rediscovery. It has been scarcely as bright as a 10th magnitude star, and it is steadily becoming fainter. On June 29th occurred the closest approach to the Sun, the distance being 1.7 astronomical units, or 160,000,000 miles. Near the middle of June it was nearest the Earth; at that time the distance was 65,000,000 miles. During most of the present apparition, Kopff's comet has remained in the southern part of the constellation

Aquila, its motion has been eastward, and slowly northward. It will doubtless be followed for some weeks more before it gets beyond the range of large telescopes. Kopff's comet is interesting mainly in that it is periodic. It is one of the many comets belonging to the *Jupiter* family. If undisturbed this comet should reappear in the early part of 1926.

A much more interesting comet is the second of 1919, discovered by Rev. Joel H. Metcalf, at Camp Idlewild, Vermont. This comet, first announced as an unexpected one, was found by Professor Leuschner to be identical with Brorsen's comet of 1847.

At the discovery date, August 20th, the comet was in the constellation *Pegasus*. It moved rapidly northwest, thru the constellations of *Cepheus* and *Draco*, and in less than two weeks it had reached a high northern declination. At the same time the brightness increased till it was brighter than the 7th magnitude; perhaps it might have been seen by a keen eye without telescopic aid. Then it turned south again, and at the present time is in the constellation *Ursa Major*, and is steadily moving southward and towards the Sun. By the first of October it will be so close to the Sun as not to be visible, and a little later it will be beyond the Sun, in the morning sky. It will remain in the morning sky for some time, rising a little before the Sun, and observation of it will not be very easy. Since the beginning of September the brightness has been steadily diminishing.

Metcalf's first comet will be at a least distance of 45,000,000 miles from the Sun on October 16th. It was closest to the Earth on September 5th, the distance being 18,000,000 miles. Now it is increasing rapidly, which accounts for the diminishing brightness and slower apparent speed across the sky.

The preliminary elements were computed at the Lick Observatory by Miss M. L. Heger and the writer. It was from these elements that Professor Leuschner announced the identity with Brorsen's comet of 1847. Two other sets of elements have now been derived, using a larger time interval, which quite conclusively show the character of a long-period ellipse. The period of 72 years shows that the comet belongs to the *Neptune* family, the one of which Halley's comet is also a member.

In appearance Brorsen's comet is not striking. It is quite diffuse, condensed in the center, but with neither nucleus nor tail.[1] Nor is there any record of its having presented unusual features at its appearance in 1847. It will be observed as long as possible, of course, in order to furnish observational material with which to determine the time of its next apparition.

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[1] No tail is visible to the eye. See note by Nicholson and Humason on photographs of the tail.

The third comet of 1919 was also discovered by Rev. Joel H. Metcalf. This comet was likewise unexpected, and is, so far as we know now, new.

At discovery it was in the constellation *Bootes*. The motion, in comparison to Metcalf's first comet, is rather slow. It has been moving slowly southeastward, and by the first of October it will have moved from *Bootes* into the southwestern part of *Serpens*.

Preliminary elements for this comet were also determined at the Lick Observatory by Miss M. L. Heger and the writer. These elements suffice to show the principal characteristics of the orbit. Deviation from a parabola is not yet manifest, tho with a longer arc it might become so. The perihelion passage, or closest approach to the Sun, does not occur till December 18th, and the distance from the Sun is about 150,000,000 miles. At the present time the comet is slowly approaching the Earth also, but after the first part of October the distance will increase. At the present time the distance is about 230,000,000 miles.

In appearance it is very different from Metcalf's first comet, in that it has a sharp nucleus. The surrounding nebulosity is more condensed, but there is no tail. In brightness it seems to be equal to an 8th magnitude star.

The comet will be followed for some time before it is lost in the rays of the Sun. Not till early next year will it be beyond the Sun in the morning sky and it will then be far south and at a great distance from the Earth. Perhaps it may be observed at some southern observatory.

H. M. Jeffers.

Lick Observatory,
September 20, 1919.

Measures of the Disk Surrounding Nova Aquilae, No. 3

Nova Aquilae was examined with the 36-inch refractor on four nights from August 17th to September 4th, using the 520 and 1000-power eye-pieces. At the ordinary stellar focus the nova appears as a yellow-white star surrounded by a bluish-green nebulous atmosphere which forms a halo more than five seconds of arc in diameter. When the focussing tube is drawn out the enveloping halo reduces in size and is condensed to a vivid bluish-green disk in which the out of focus image of the star is entirely lost, except for a faint yellowish fringe to the disk. The green color is of course due to the fact that the nebulium bands (centers at 5007A and 4959A) are by far the strongest in the spectrum of the disk.[1]

The disk is reduced to its minimum size when the tube has been drawn out about 0.3 inches (8 mm.). It is then approximately circular in outline and its surface is of nearly uniform brightness. At moments it has a slightly mottled appearance, perhaps due to out of focus light from the central star.

On two nights micrometer measures were made to determine the diameter of the disk at its sharpest focus and to see whether or not there was any departure from circularity. The results are as follows, the figures in degrees giving the position angle of the diameter measured.

	202°	157°	112°	67°	Mean
August 20	2″.44	2″.22	2″.34	2″.42	2″.36
	180°	135°	90°	45°	
September 2	2″.45	2″.34	2″.33	2″.40	2″.38

Particular care was taken not to over-measure the diameters, but it is possible that the out of focus image of the star affected the apparent size of the disk to a slight extent. The error of measure due to this cause can hardly exceed one or two tenths of a second of arc, so it is safe to say that the diameter of the true disk is greater than 2 seconds of arc. It will be noticed that the measures indicate a somewhat greater diameter in the south preceding-north following direction than at right angles to this position. The differences, however, are but little larger than the probable error of measure and may have no significance.

A comparison of my measures with those made by Barnard[2] in October–December, 1918, indicates an increase in the size of the disk, a conclusion that is made more probable by an examination of Barnard's individual measures. His general mean is 1″.18, but the three measures in October give 0″.65, the two in December (made when the object was very low in the sky) 1″.84, while those in November give intermediate values.

Robert G. Aitken.

September 8, 1919.

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[1] See the article by Moore and Shane on page 269 of this number.

[2] *Astrophysical Journal*, **49**, 199, 1919.

THREE NEW PLANETARY NEBULAE

During the past summer I have included in the observing list of the Crossley reflector a number of objects very close to the plane of the Milky Way. The descriptions of the objects in the NGC were of such a character as to raise the suspicion that these might be faint clusters, or even spirals. Most of these nebulae have proved to be of the diffuse type; one or two are faint star clusters. Three nebulae, from the evidence of their form, are undoubtedly planetary nebulae.

NGC I 1295; $18^h 49^m.2$; $-8°55'$.

Exceedingly faint; a faint, hazy ring about 2′ x 1′.5, in p. a. 90°±. The central portions are relatively vacant, and it is fainter along and at the ends of the major axis. There are three faint stars at the center, of which one is probably the central star.

NGC 6842; $19^h 50^m.9$; $+29°1'$.

Very faint. It is about 50″ x 45″, showing traces of an irregular ring formation. It has a central star of about the 13th magnitude.

NGC 7048; $21^h 10^m.7$; $+45°53'$.

A rather faint oval, with slight traces of ring structure. It is about 60″ x 50″ in p. a. 20°±. The brightest portions are at the east end of the minor axis. There is a very faint central star.

The spectrum of NGC 7048 has been examined visually with the 36-inch refractor by Messrs. Campbell and Moore, and found to be gaseous.

HEBER D. CURTIS.

September, 1919.

THE ORBIT OF THE VISUAL BINARY SYSTEM β 1111

One of the practical exercises assigned to my class in the theory of orbits of binary stars at the recent Summer Session of the University of California was the computation of the orbit of β 1111 by the Glasenapp-Kowalsky method. The four members of the class were encouraged to draw many apparent ellipses and to use each his own judgment as to the ellipse best satisfying the observed distances and the law of areas. The result was the four independent sets of elements which follow:

	M. V. Cannon	H. C. Hicks	J. F. Pobanz	H. G. Wrocklage
$P=$	42.18 yrs.	39.26 yrs.	39.67 yrs.	42.07 yrs.
$T=$	1917.87	1919.35	1918.90	1918.20
$e=$	0.248	0.222	0.234	0.245
$a=$	0″.220	0″.412	0″.241	0″.244
$\omega=$	137°.4	165°.7	146°.3	135°.4
$i=$	34.8	34.8	43.0	45.85
$\Omega=$	43.5	37.8	46.0	46.7

Differential corrections to these orbits were undertaken by each student, but the six weeks' session was too short to permit the completion of the work. I have recently carried out such corrections, taking as basis a set of elements derived by interpolation from the four sets given above after a study of the corresponding sets of residuals. When my equations were set up it developed that the coefficients for $\Delta\Omega$ and $\Delta\omega$ were nearly identical. The node was therefore assumed to be known and the solution then carried thru for the remaining elements. The results are as follows:

Elements	Ephemeris		
$P = 40.53$ years	1920.38	219°.1	0″.18
$T = 1918.38$	1921.38	229 .5	0 .19
$e = 0.238$	1922.38	239 .6	0 .19
$a = 0''.235$	1923.38	249 .5	0 .19
$\omega = 144^\circ.35$	1924.38	259 .5	0 .19
$i = 40.8$	1925.38	269 .6	0 .19
$\Omega = 43.95$	1926.38	279 .8	0 .19

MEASURES AND RESIDUALS (O–C)

Date	θ_0	ρ_0			$\Delta\theta$	$\Delta\rho$
1889.14	315°.3	0″.19	3*n*	Burnham	+2°.2	0″.00
1890.43	321 .2	0 .25±	2	Schiaparelli	−3 .7	+0 .05
1892.17	336 .1	0 .21	4	Burnham	−3 .1	−0 .01
1898.52	18 .7	0 .28	7	Burnham and Aitken	+1 .2	+0 .01
1899.30	28 .8	0 .25	1	Lewis	(+7 .6	−0 .03)
1900.20	27 .8	0 .29	3	A.	+2 .3	+0 .01
1901.39	31 .3	0 .28	4	A.	+0 .4	0 .00
1902.34	42 .9	0 .25	1	A.	(+7 .7	−0 .03)
1903.39	38 .3	0 .28	3	A.	−1 .8	0 .00
1905.33	50 .9	0 .25	3	A.	+1 .4	−0 .02
1907.38	60 .5	0 .26	2	A.	0 .0	+0 .01
1910.55	75 .0	0 .17	1	A.	(−8 .4	−0 .03)
1911.49	89 .3	0 .21	2	A.	−3 .2	+0 .03
1912.21	92 .6	0 .18	1	A.	(−8 .2	+0 .01)
1914.46	125 .7	0 .17	3	A.	−2 .0	+0 .02
1916.37	165 .8	0 .17	3	A.	+0 .2	+0 .02
1918.42	189 .2	0 .18	1	A.	(−5 .7	+0 .01)
1919.45	207 .4	0 .16	3	A.	−1 .2	−0 .02

The sum of the squares of the residuals in angle for the separate observations (not the normal places) was reduced only from 393.6 to 343.6; but, if the five residuals enclosed in parentheses are omitted, the reduction is from 122.9 to 56.0. It will be noted that these residuals relate to positions each of which depends upon a single night's measure, and it is obvious from the general run of residuals that they are chiefly due to errors of observation. No essential improvement was made in the representation of the observed distances, the sum of the squares of the residuals being reduced only from .0090 to .0083.

ROBERT G. AITKEN.

September 11, 1919.

GENERAL NOTES

The Twenty-third Meeting of the American Astronomical Society.—The meeting was held in Ann Arbor, Michigan, September 2-5, and again we experienced the hospitality of a college town and have added the University of Michigan to our long list of hosts. The meeting was held in conjunction with the American Mathematical Society and the Mathematical Association of America. Nothing was overlooked by the committee of arrangements which would add to our comfort. The Newberry Residence, a woman's dormitory, was opened for our use, and two ladies came especially to take care of it for our benefit. The Michigan Union, a great club house for the Alumni not yet finished, opened its artistic grill room for us, and a corps of young women volunteered to act as waitresses without compensation.

A reception was given to us at the Observatory house one evening, during which there was an opportunity of inspecting the instruments and seeing the great spectrograph put to work. The mirror is covered by a large closet which is never opened until the temperature outside and inside are nearly the same. The new building gives plenty of space for office and student use, as well as room for the library. We were also entertained at luncheon here.

Perhaps the most interesting social function was the joint dinner given by the three societies, at which nearly two hundred people were present, including several residents of the city. The speeches at this dinner forever dispelled the illusion that scientists can not be entertaining, for the speakers scintillated with wit, and a remarkable collection of amusing stories was told. The toastmaster was Professor Slaught of the University of Chicago, who was in a most happy vein. Addresses of welcome were given by Mr. Beal, the resident regent, and Professor Beman of the Mathematics department. These were responded to by representatives of the three societies, our own being Dr. Schlesinger. Dr. Klotz of the Dominion Observatory at Ottawa was called upon to speak for our sister to the north. Introducing a serious vein, he begged us in view of the present great crisis not to forget the great human things in our pursuit of the pure sciences, and defined culture as moral, intellectual and aesthetic reverence. Dr. Stebbins told some amusing personal experiences at the International Conference in Brussels. Professor Hedrick of the University of Missouri described his work with the schools for soldiers in France after the armistice. He depicted in a thrilling way the response of the men and the great need in our own country of more interest on the part of intellectual leaders in the general education of the people. Personally, I was very glad that some reference was made to this problem. We all see the confusion of thought that reigns in the public mind at the present time, and no group of trained thinkers should come together without expressing in some way their responsibility toward an education which will help to produce clear and straightforward thinking.

Since abstracts of the papers presented will be published in *Popular Astronomy*, it is not necessary to give any detailed report of them here, tho some interesting points may be noted. The slides for Dr. Pettit's paper on the prominence of May 29, 1919 (the date of the total solar eclipse) were very fine, showing wonderful details of structure and remarkable motion. The same prominence appeared on Dr. Bauer's slide of the eclipsed Sun taken on the same date in Liberia.

Professor Brown informed us that he was preparing a simplified treatment of the theory of probabilities suitable to teach to Freshmen. He said that the Law of Least Squares is the integrated experience of humanity.

Very great interest was shown in Dr. Hale's account of the testing of the comparative efficiency of the 60-inch and 100-inch telescopes, and the slides were called for a second time.

At the election of officers, Dr. Schlesinger was unanimously elected to serve as our next president, and when called upon for a speech, he thanked us for the confidence we had shown by electing him to succeed two such distinguished men as Newcomb and Pickering.

The spirit of the meeting was one of friendly comradeship and coöperation, but we were sorry not to have any representatives from the two great observatories in California. The place of the next meeting was not announced, but I think all agreed in preferring a college town to a large city.

CAROLINE E. FURNESS.

Vassar College.

The Planets in the Morning Sky.—To early risers the last quarter of the present year offers unusual opportunities for the study of the apparent motions of the planets.[1] *Mars*, *Jupiter*, *Saturn* and *Neptune* are apparently near neighbors on October 1st. *Mars* was in conjunction with *Jupiter* on September 2nd and will gradually draw away from it toward the south and east during the rest of the year. About 4 A. M. on October 24th it passes within 5′ of *Saturn*, as Professor McNeill has pointed out. The two planets will then form a remarkably bright, close "double star," as viewed without a telescope, for 5′ is less than twice the limiting distance at which two stars can be seen separately with the unaided eye. *Neptune* is a little over a degree west and south of *Jupiter* on October 1st, and the distance between them will not increase greatly by the end of the year, but, of course, *Neptune* cannot be seen without a telescope.

Venus is visible south and east of these four planets thruout the quarter year and is, indeed, the brightest star-like object in the sky. Still nearer the southeastern horizon *Mercury* may be seen on very clear mornings in December; and the waning Moon, as it approaches the new-moon phase in each month, will prove an added attraction. *Uranus* is the only absentee. It is on the other side of the Sun and is visible in the evening sky in the southwest.

Doubtless those who read in the stars prognostications of terrestrial events will find in this beautiful grouping of the planets the warning of some great calamity; for it is a noteworthy fact that their prophecies are always of evil, never of good. One such seer has already published his warning in the daily papers. A year ago he also made the "discovery" that the influenza, then epidemic, was caused by the presence of *Jupiter* at the node of its orbit! Just how, he did not trouble to explain; nor did he tell us why (since *Jupiter* passes one or the other of its two nodes every six years, its revolution period being 11.86 years) we have not had thruout the centuries an influenza epidemic every six years, or every twelve years if the planet breeds pestilence at but one of its nodes.

A Southern Star Catalog.—Volume V of the publications of the La Plata Observatory consists of a catalog of 7412 stars in the zone −52° to −57° declination (1875) for the epoch 1925 prepared by

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[1] See Professor McNeill's *Planetary Phenomena* in the present number and the August number of these PUBLICATIONS.

Paul T. Delavan. In a general way, it was the purpose of the work to extend the plan of the Astronomische Gesellschaft to the more southern skies, and this volume is to be followed by a similar one for the zone −57° to −62° based on observations made by Señor Felix Aguilar. But the working list, including all stars as bright as 9.0 magnitude, is taken from the *Cape Photographic Durchmusterung* rather than from the *Cordoba* (visual) *Durchmusterung*; and the *Catalogue of 687 Standard Stars* by Lewis Boss is adopted for the fundamental stars instead of the fundamental catalog of Auwers. In general, at least two observations, one in each position of the instrument, were secured for each star, the average number being 2.43. A few stars were measured in part or wholly with the equatorial telescope. The probable error of a catalog position is 0″.28 in each coördinate, an accuracy which compares favorably with the best of the A. G. catalogs.

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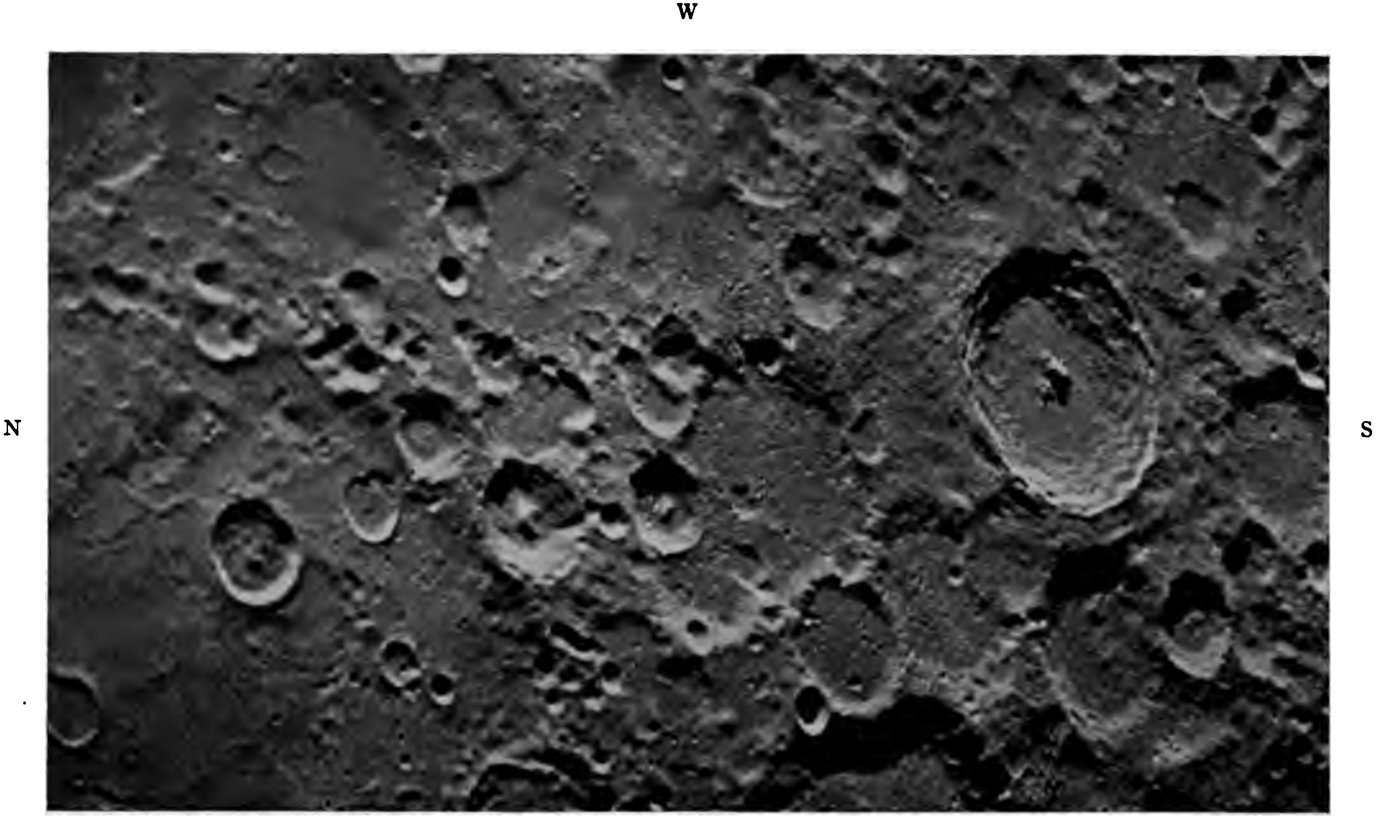

Tycho and Region to the North

Photographed by F. G. Pease with the 100-inch Reflector, September 15, 1919. Enlarged 2.8 times

PUBLICATIONS
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THE FUTURE OF THE TRANSIT-CIRCLE

By J. E. de Vos van Steenwijk

The importance of the transit-circle has waned considerably during the last fifty years. Much of the work to which it was originally destined has been completed or needs only intermittent attention. Another part has been taken up by special instruments *e. g.* the zenith-telescope. A still greater part has fallen into the domain of photography. So it may justly cause some perplexity if a new program has to be started now and one may feel inclined to think that the activity might be better directed wholly to other instruments. The aim of this article is to show that our transit-circles may be used in more than one way to solve some of the great problems concerning the structure of the universe where other methods will fail.

Before arguing this point I shall briefly review the different tasks that are now incumbent on meridian observers and the amount of work necessary to their completion.

Our fundamental systems, at least for the northern hemisphere, may be said to rest on a sound basis. Altho regular observations will always be needed to maintain them on this height and automatically to increase their excellence, it can hardly be said that an important fraction of the available instruments are needed for this purpose. This part of the work may be left to great and old-established observatories such as Greenwich, Pulkowa and the Cape of Good Hope, because continuity and an intimate knowledge of the instruments used, play such a great part in it.

A second question is the acquisition of an extended body of fundamental proper-motions. The repetition of the A. G. zones and their extension to the South Pole form here the natural solution. But before embarking on such an extensive enterprise it behooves us to investigate very thoroly whether this burden could not be taken off the shoulders of meridian observers also. It has been argued from more than one side that by using a portrait lens and a wide-angle camera the whole repetition of the A. G. Catalog might be completed by a single observatory in a few years, leaving only a few thousand reference stars to be determined by meridian observations. For this last purpose the so-called *intermediate stars* of the Astrographic Catalog, which number more than six thousand in the northern hemisphere alone, and have been chosen with the utmost care, would be amply sufficient and no extra work would be needed.

For comparison stars in micrometrical work the reference stars of the same catalog give all that can be desired.[1].

A new field was opened in 1886 by Kapteyn, who used the transit-circle for parallax determinations. His example was followed by Flint and, after the introduction of the registering-micrometer, by Groszmann and lately by Voute at the Cape. The prospects for this method are judged differently. Courvoisier, who tested it by a re-determination of the accurately known parallaxes of γ, δ and ϵ *Ursae Majoris* (which belong to a well-known moving cluster), concluded that at least the hand-driven micrometer is not to be trusted in this respect. On the other hand Groszmann has strongly advocated the use of the method and has even started a coöperative scheme, of which I believe he is at present the only active member. The question whether or not systematic errors are to be feared here must be fully elucidated. That the accidental errors are greater than in photographic results does not tell much against the method as I should like it to be used.

I should think it an immense advantage if a Durchmusterung for parallaxes by meridian observers were to show photographic and heliometric observers where their energies ought to be directed. If we only succeed in sifting out a small percentage of stars suspected of having measurable parallaxes, the present undesirable method of choosing stars with great proper motions could be abandoned. We must not forget that, while secular parallaxes furnish excellent material for researches into stellar astronomy, the knowledge of our immediate neighborhood depends wholly upon individual parallaxes and is proceeding slowly by the present methods.

I will now develop my suggestion as to a new line for transit-circle research. It is based on the following considerations:

Much insight into the structure of the universe has been gained by the discussion of the relations between proper motion and spectral type. But in the catalog from which these proper motions have been deduced the spectral type was never taken into account, nor indeed could this have been done at the time. The result is that they consist mainly of stars of types I and II, while type III (M) is scarce and types IV (N) and V (O) are almost wholly wanting. In the researches of L. Boss and Kapteyn, for example (Eddington, *Stellar Movements*, p. 167), the number of M stars attains only ten per cent of those of types I and II each, and N and O are absent. Now this is an inconvenience which photography could never remedy. When the plan of selected areas shall be completed, its results again will refer mainly to types I and II. This difficulty is accentuated for the M and N stars by their red color, which renders them so faint on the photographic plate.

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[1] Except for the Zodiac, for which the Paris Conference has prepared a special catalog.

It seems to me, therefore, that the time has come when we should cease to choose our stars for meridian observations by the criterion of magnitude or apparent place, which are both irrelevant to their constitution or location in the universe, and might properly be termed a non-natural classification. Most happily the new Draper Catalog affords us a wide scope for selecting an observation list based on spectral type and where it fails the color index furnishes a rough substitute.[2]

Granting this point, the first thing must be to supplement our scanty data as to the M stars. The first four hours of the new Draper Catalog contain 483 of them, or nearly two per cent of the whole, so that we may expect that about 4400 M stars will soon be known in the sky. Many of these will be found in the A. G. Catalogs, and for them tolerably good proper motions might be obtained in the near future. The M stars are especially interesting owing to the appearance of the so-called dwarfs and giants. Nothing is known as yet as to the relative frequency of these two among the fainter stars and considerable extension of our knowledge may be expected from more and more reliable proper motions.

For the stars of type N the outlook is decidedly less bright. The Draper Catalog will probably contain only some hundred of them, and the color index is not a sufficiently sharp criterion to distinguish them from the M stars. Indeed, by selecting faint stars with a high color index (as might be done by comparing the magnitudes of the astrographic catalog or the C. P. D. with those of a visual Durchmusterung) we are sure the results will bear almost exclusively on M stars.

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[2] A first step in this direction are the meridian observations at Kopenhagen of B and M stars by Braae, and of N stars by Nörlund.

A catalog of 166 N stars has been observed by Nörlund at Kopenhagen, who deduced for 144 of them proper motions. Kapteyn discussed these and found a mean parallax of only 0".0007 with a probable error of the same magnitude. From this it would appear that they are on the whole ten times more distant than the helium stars, which is very interesting owing to their strong galactic concentration. But Nörlund based his determinations on a number of older catalogs which I should hesitate to use for such a refined purpose. He does not give the probable errors of his concluded proper motions, but I fancy that they would considerably exceed the proper motions themselves. I think that his observations form only a valuable material at an initial epoch.

SUMMARY

1. The observing of fundamental stars ought to be left entirely to a few of the greatest observatories.
2. Experiments[3] should be instituted whether or not a repetition and extension of the A. G. zones could be effected with the aid of photography, while the intermediate stars of the astrographic catalog might be used as reference stars.
3. In view of the preceding, meridian work on secondary stars should be restricted to the needs of the moment.
4. A Durchmusterung for parallax by meridian observers has not yet lost its importance.
5. Meridian observations should further be directed into channels where photographic research encounters special difficulties, *e. g.* systematic observations of stars of type M, that are too sparsely distributed for examination by samples as in the plan of selected areas.

POST SCRIPTUM

I have made some counts of the M stars contained in the first part of the Henry Draper Catalog. Of the 483 M stars found, 263 belong to one or more of the A. G. zones, including the Cordoba zone $-22°$ $-27°$; of the remaining, only 38 inside those zones are not found in the A. G. catalogs. Twenty-six M stars were found among the reference stars of the Perth and Cape sections of the astrographic catalog.

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[3] Such an experiment has been in progress at the Allegheny Observatory for several years and the results are very satisfactory. The photographic star places are at least as accurate as the older A. G. zone positions, and the cost of obtaining them is much less.—The Editors.

ON THE IDENTITY OF A PAIR OF STRONG LINES OF PECULIAR BEHAVIOR IN THE SPECTRA OF NOVA AQUILAE III

BY F. E. BAXANDALL, A. R. C. SC.

In a paper[1] on "Movements of Four Unknown Lines in the Spectrum of *Nova Aquilae*," Mr. Paddock gives an account of two pairs of unidentified absorption lines which appear intermittently in the spectrum of *Nova Aquilae*, and which show conspicuous changes of position or wave-length. "In each pair the two lines have appeared and disappeared together, maintained equal intensities and practically constant distances apart, moved equal amounts at the same time, and in all respects have behaved like duplicates."

The present note relates to the more refrangible of these pairs, the greatest observed wave-lengths of which were, according to Mr. Paddock's measurements, λ4061, λ4068. In reference to these he states, "The distance between the lines ranged from 5 to 7 Angstroms. . . . . These variations are probably due to changing widths and appearances and it is very probable that the lines possess a constant difference of wave-length."

Plaskett in a paper,[2] "Notes on the Spectrum of *Nova Aquilae* No. 3," refers specially to the same pair of lines and their curious behavior.

An investigation of a set of spectra of *Nova Aquilae* kindly sent by Dr. Plaskett (being glass copies of the originals photographed by him at the Dominion Astrophysical Observatory, Victoria, B. C.) has led me to the view that the pair of anomalous stellar lines is probably identical with a pair of nitrogen lines at λλ4097.4, 4103.4, which show an abnormal behavior in laboratory spectra. An account of this abnormality was fully given in a paper[3] "On the Origin of Certain Lines in the Spectrum of ε *Orionis*," by Lockyer, Baxandall and Butler. There is no need to refer here to that paper in much detail, but it was shown that the stronger component at λ4097 of this pair of nitrogen lines occurred conspicuously in some of the spectra of the early B type (such as ε and κ *Orionis*) and in 29 *Canis Majoris*, where it is almost as strong as the adjacent Hδ line. The other member, λ4103.2 is so near the Hδ line that in stellar spectra of the type containing the nitrogen and hydrogen lines the former would usually be masked by the broad and strong Hδ line. Reference may here be made, however, to a paper by Professor Frost[4] in which it appears almost certain that he has recorded in the spectrum of 10 *Lacertae* both components of the pair under discussion, the Hδ line in his spectrum apparently being so narrow as not to coalesce with the adjacent nitrogen line. He has, however, suggested an identification of his λ4103 line with a "silicon (?) line." The silicon line at this wave-length is an arc or low temperature line, and its identification with the line in a stellar spectrum of the type discussed by Professor Frost is improbable. The presence of the comparison nitrogen line λ4097 in Frost's spectrum makes it far more probable that the stellar line λ4103 is ascribable to nitrogen.

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[1] *Pub. Ast. Soc. of the Pacific*, Vol. 31, page 54.
[2] *Journ. Ast. Soc. of Canada*, 1918, page 350.
[3] *Proc. Roy. Soc.*, Vol. 82, page 534.

Reference may here be made to the apparently abrupt change which Mr. Paddock records for July 1st, when the displacement of the strange pair is vastly greater than for any other day. From an examination of Plaskett's plates it seems almost certain that the pair of lines here accepted by Paddock as identical with that of the other days is another pair of lines altogether, and has no connection with the double discussed by him on other days. In fact, Plaskett's plate for July 1st shows another double in almost the same position as Paddock's usual double, altho it is not very pronounced.

The mean interval apart of the lines constituting Paddock's pair is 6.3 tenth meters. The interval between the two abnormal nitrogen lines is, according to Exner and Haschek's wave-lengths, 6.0 tenth meters. The stellar lines are always broad and diffuse and Paddock's wave-lengths given only to the nearest tenth meter.

The evidence on which the identity of the stellar and nitrogen lines is based may now be given.

In the study of the absorption lines in Plaskett's spectra it was found that from June 13th onwards the ordinary spark lines of nitrogen and oxygen, displaced some 30 to 40 tenth meters to the violet from their normal position, play a prominent part in the spectra. (The identity of lines at certain stages of the spectrum of *Nova Geminorum* II with lines of these gases was recently pointed out by Stratton.[5]) In the earlier spectra of *Nova Aquilae* III, up to June 13th, the enhanced lines of Fe, Ti, Cr, Mg, etc. (so conspicuously shown in *α Cygni*) had been a prominent feature. In succeeding spectra from June 13th onwards these lines gradually lose their strength, and altho on the 15th there are many of them still persisting, most of them are only of low intensity. At this stage the nitrogen and oxygen lines have developed considerably so that such well-known lines as 3995N $\left.\begin{matrix}4070\\4072\\4076\end{matrix}\right\}$O $\left.\begin{matrix}4317\\4319\end{matrix}\right\}$O and $\left.\begin{matrix}4415\\4417\end{matrix}\right\}$O and the whole of the strong air group from 4591 to 4676 can readily be recognized. Paddock's pair of lines at the measured positions near λλ4061, 4068 were found, whenever the presence of other nitrogen lines in the spectrum made comparison possible, to be ascribable to the two abnormal nitrogen lines at λλ4097, 4103, partaking of the same velocity displacement as many other well-authenticated nitrogen and oxygen lines in the spectrum of *Nova Aquilae*.

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[4] *Aph. Jour.*, **40**, 270, 1914.

[5] *Monthly Notices, R. A. S.*, **79**, 366, 1919.

No light on the identity of Paddock's second double in the measured positions near λλ4560, 4576 has been obtained in the investigation of Plaskett's spectra.

Solar Physics Observatory
Cambridge University,
September 6, 1919.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1920

BY MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME

Full Moon.......Jan.	5, 1^h 5^m P. M.	Full Moon.....Feb.	4, 12^h42^m A. M.
Last Quarter..... "	12, 4 9 P. M.	Last Quarter... "	11, 12 49 P. M.
New Moon...... "	20, 9 27 P. M.	New Moon..... "	19, 1 35 P. M.
First Quarter.... "	28, 7 38 A. M.	First Quarter... "	26, 3 49 P. M.

The Earth comes to perihelion, reaching its least distance from the Sun on January 3rd, 2 P. M., Pacific Time.

Mercury begins the year as a morning star, having passed greatest west elongation on December 21st. It gradually nears the Sun and passes superior conjunction on February 5th, becoming an evening star. By the end of the month it has nearly reached greatest east elongation. There are, however, only moderately good conditions for visibility either as morning or as evening star. During the first few days in January it rises a few minutes more than an hour before sunrise and may be seen if weather conditions are favorable. At the end of February the conditions are somewhat better from the standpoint of the interval between the setting of the Sun and of the planet, and the planet is two or three times as bright on February 29th as on January 1, 1920, so that it will be a comparatively easy object for naked-eye view during the last few evenings of February. The principal reason for this increased brightness in February is the fact that it passes perihelion on February 29th. On February 13th it is in conjunction with *Uranus* passing about 1° south of the latter.

Venus is also a morning star on January 1st and will continue to be so until early July, when it passes superior conjunction with the Sun. On January 1st it rises more than three hours before sunrise, but this interval diminishes to less than an hour and a half by the end of February. The apparent distance between Sun and planet diminishes only about one-third during the two months, while the planet's motion relative to the Sun brings it much farther south of that body and causes a marked dimunition of the interval between the rising of the planet and the Sun. The planet is in the part of its orbit farthest from the Earth, but its brightness is still much greater than that of any heavenly body except the Sun or the Moon.

Mars during 1919 was not in good position for observation, but 1920 is comparatively a good year, as the planet will come to opposition on April 21st. It will be an easy object during the whole of the year and during the spring and summer quite a prominent one, altho not nearly as bright as it is when the opposition comes in August. This will happen in 1924. On January 1st it rises shortly before 1 A. M., and at the end of February at about 10:30 P. M. During the two months it moves about 20° eastward and 7° southward from a point in *Virgo* near the first magnitude star *Spica*, *a Virginis*, to a point in *Libra*. Its distance from the Earth grows rapidly less, the diminution being fifty-five millions of miles, about 40% of its January 1st distance. Mainly in consequence of this its light more than doubles. On January 1st it is not quite as bright as a standard first magnitude star, being just about as bright as *Spica*, the star east and south of the planet, the ruddy color of the planet easily distinguishing it.

Jupiter is in fine position for observation as it comes to opposition with the Sun on the evening of February 2nd, then rising at sunset and setting at sunrise. On January 1st it rises less than three hours after sunset; at the end of February it sets more than an hour before sunrise. It moves from the western part of *Leo* into *Cancer* 7° westward and 2° northward. As the distance of the planet from the Earth varies relatively much less than that of *Mars*, the variation in brightness is also much less, but it will lose nearly half of its brightness by the time it reaches conjunction in August. As the Earth is nearly in the plane of the satellites' orbits the apparent motion of the satellites is nearly rectilinear forward and backward across the disk of the planet.

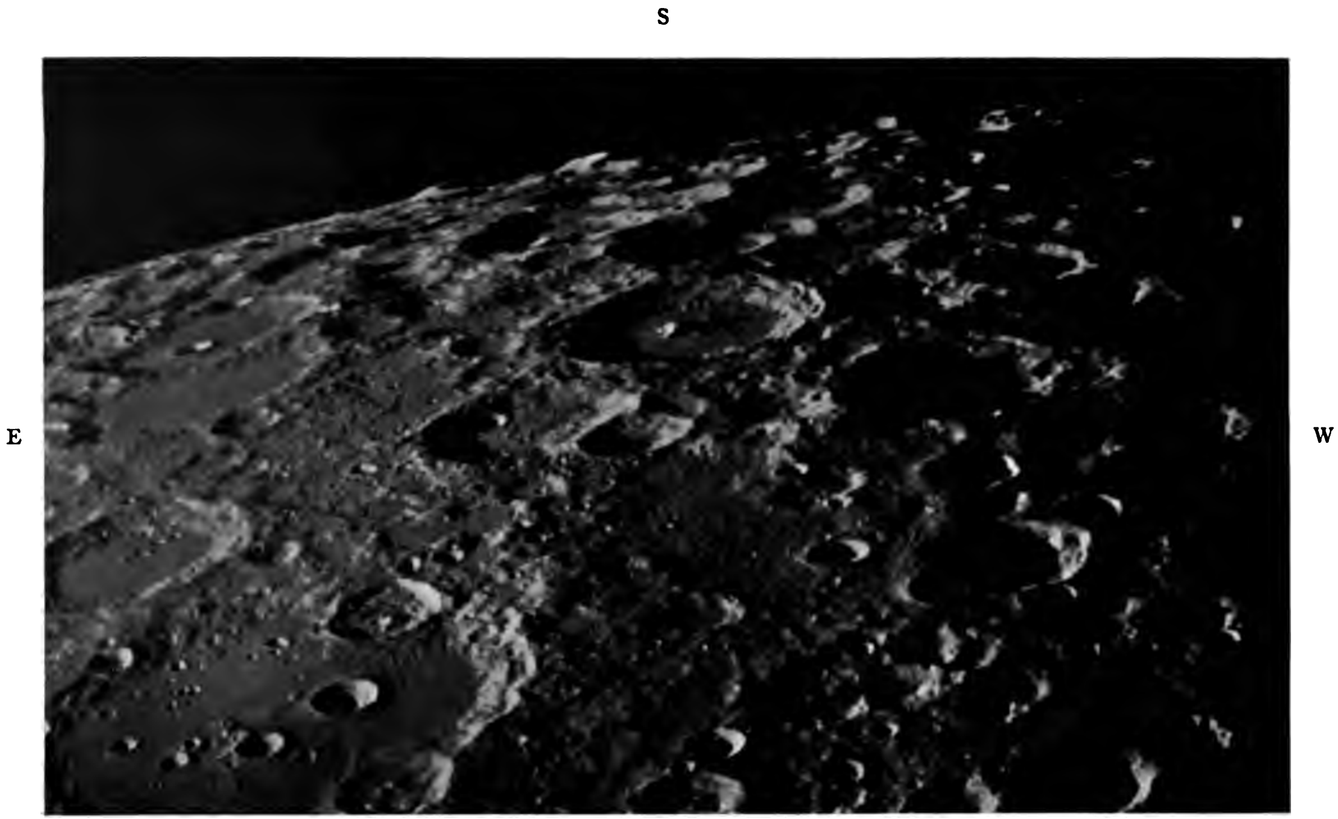
Saturn is also in fine position for observation to the eastward of *Jupiter*. It comes to opposition with the Sun on February 27th. On January 1st it rises shortly before 10 P. M. and at the end of February a little before sunset. It is in the constellation *Leo* and like *Jupiter* is moving westward and northward, but only about half the amount. The brightest star in *Leo*, *Regulus*, lies between the two planets.

Uranus is in the southwestern sky in the evening but is too close to the Sun for naked-eye view. It passes conjunction with the Sun and becomes a morning star on February 21st. Its conjunction with *Mercury* on February 13th has already been mentioned.

Neptune is in the same part of the sky as *Jupiter* and comes to opposition with the Sun at midnight January 30th, about three days before *Jupiter*. It is too faint for naked-eye view.

CHANGE OF ADDRESS

Notice is given that the headquarters of the Astronomical Society of the Pacific have been removed to Room 709 Postal Telegraph Building, 22 Battery St., San Francisco. Communications for Mr. D. S. Richardson, the Secretary-Treasurer of the Society, should be sent to this address.



Moretus, Clavius, Etc.
Photographed by F. G. Pease with the 100-inch Reflector. Enlarged 2.8 times

NOTES FROM PACIFIC COAST OBSERVATORIES

THE SPECTRUM OF COMET *b* 1919 (BRORSEN-METCALF)

Two spectrograms were recently secured here of Comet *b*, 1919. The first plate, exposed on the morning of October 17th, was rather weak, due to a hazy sky, and a second exposure was made on the following morning under a better sky. The second plate was measured and the results are tabulated below. In a parallel column will be found the main details in the spectrum of Comet *b* 1914 (Zlatinsky), observed with the same instrument. The spectrum of the early comet is reproduced in *Lowell Observatory Bulletin* No. 74, to which the reader may wish to refer, since the spectral resemblance is fairly close, altho the emissions from near λ4000 to λ4100 are weaker in the present object. The continuous spectrum is faint in the Brorsen-Metcalf comet. This comet passed perihelion October 16th, and its distance from the Earth was about nine-tenths the astronomical unit and increasing.

Comet *b* 1919 Brorsen-Metcalf	Comet *b* 1914 Zlatinsky	Remarks
5163	5164	3rd carbon band, partially resolved
5126	5128	3rd carbon band, poorly resolved
4735.2	4735.3	4th carbon band, strong, clear
4714.9	4714.2	4th carbon band, strong, clear
4697.1	4695.7	4th carbon band, strong, clear
4677	4679	4th carbon band, blend
4544	4543	Region of 1st cyanogen band, weak
4371.1	4370.5	“ “ weak, but distinct
4364.1	4363.9	“ “ fairly strong, distinct
4313.5	4313.3	“ “ very sharp
4214.6	4214.9	1st edge, 2nd cyanogen band, strong
4198±	4195.9	“ “ diffuse
4073.8	4073.7	Unidentified, weak
4066.6	4066.5	Unidentified, weak
4050.6	4051.5	Unidentified, weak
4042.1	4042.4	Unidentified, weak
4020.3	4020.2	Unidentified, weak
4016.1	4014.4	Unidentified, weak
3881.1	3881.1	1st edge, 3rd cyanogen band, very strong
3868.2	3868.3	“ “ wide blend

The linear scale of these spectra, 7 mm. from λ5165 to λ3883, and the fluting nature of the bands are against accurate wavelength determinations. The agreement between the results for the two comets is as good as might be expected and the occasional difference found should not be interpreted as implying necessarily real difference in the bands.

I am indebted to Mr. O. H. Truman for reducing the measures and for computing the radial velocity corrections to the wavelengths.

Lowell Observatory, V. M. SLIPHER.
Flagstaff, Arizona.

STATIONARY SODIUM LINES IN SPECTROSCOPIC BINARIES[1]

From the nature of a spectroscopic binary it seems reasonable to expect that the velocities given by the separate star lines on a single plate should be in mutual agreement. This has been found to be the case normally, the displacements of the star lines on any one plate corresponding to the same velocity. However, the H and K lines of calcium occasionally offer an exception to this usual behavior. In a number of early type spectroscopic binaries these lines remain practically stationary thruout a periodic variation of large amplitude in the other star lines, and moreover, they appear sharp and narrow in contrast to the broad and hazy lines characteristic of this class of spectra.

A recent investigation at the Lick Observatory has shown a similar peculiarity in the D_1 and D_2 lines of sodium. Two stars, *β Scorpii* and *δ Orionis*, were studied, these having been selected as representative of the class of variable velocity stars showing stationary H and K lines. The spectrograms which form the basis of this work were taken in the visual region with a three-prism spectrograph attached to the thirty-six-inch refractor. In this region of the spectrum but three oscillating lines were measurable and, due to their poor definition, the velocities determined from these are subject to large uncertainty. The D_1 and D_2 lines of sodium are quite sharp and better suited for exact measurement, D_2 being uniformly better than D_1.

The results of the investigation are summarized below.

1. The D lines of sodium appear sharp and narrow on all the spectrograms, resembling H and K in this particular.

2. Within the limits of observational error these lines remain stationary thruout the period. A maximum departure of 21 km. from the mean velocity can be attributed to accidental error, since the character of the lines on some of the plates makes their measurement quite inaccurate and since in this region the dispersion is small.

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[1] A detailed account of this investigation is given in *Lick Obs. Bull.*, 326.

3. A comparison of the mean velocity from the sodium lines with the mean velocity from the H and K lines, the velocity of the system, and the component of solar motion is presented in the following table:

	β Scorpii	*δ Orionis*
Mean velocity D_1 and D_2	−9.2 km.	+17.6 km.
Mean velocity H and K	−8.5	+18.7
Velocity of the system	−11.0	+15.2
Component of solar motion	−10.7	+18.1

4. On account of the uncertainty of the values from the oscillating lines and also in consideration of the comparatively few observations that were obtained, no attempt was made to determine a new velocity curve. Within the limits of their accuracy, our observations are satisfied by the orbits as determined at the Allegheny Observatory.

The close relationship between the D lines of sodium and the H and K lines of calcium in the two stars which have been studied is very striking. Both in appearance and in behavior these lines are entirely comparable. We have still to look for an explanation of the peculiarity in these lines. The agreement of the velocity obtained from the D lines with both the component of solar motion and the velocity of the system seem to favor equally the two principal hypotheses which have been suggested to explain the behavior of H and K; first, that the effect is caused by an absorbing cloud of calcium vapor stationary in space between the binary star and the observer; second, that its origin lies in some condition connected with the binary system, perhaps an envelop of calcium vapor around the system as a whole. These theories are as readily applicable to the D as to the H and K lines, but with no less uncertainty. At present it seems best merely to recognize the relation of the sodium and the calcium lines in the stars which have been studied and seek an explanation which will account for the peculiarity of both.

Mary Lea Heger.

A Variable Star with a Peculiar Spectrum

The long-period variable star R *Aquarii 233815* has been found recently to possess a very peculiar spectrum. The data concerning this star are as follows: R. A. (1900) 23 hrs. 38.6 min.; Dec. (1900) −15°50′; Magnitude, variable, 6.2 to 11.0; Period 387.2 days; Predicted maximum 1919 Nov. 22; Spectrum Md8. The following remarks appear in *Harvard Annals*, vol. 56, p. 212: "The spectrum varies from Md6 to Md9 on 11 plates. Hδ apparently changes from 50 to 80" (Hγ being assumed as 10).

A number of spectrograms recently secured with a one-prism instrument at the Cassegrain focus of the 100-inch telescope show that in addition to the characteristic features of Class Md the spectrum contains several bright nebular[1] lines. These lines appear on plates taken on the following dates:

1919 October 16
" 17
" 19 (by Mr. Stromberg)
November 1 (by Mr. Adams)
" 7
" 9

During this period the magnitude of the star increased from 8.5 to nearly 7.

The spectrum may be described as a combination of that of a gaseous nebula with that of a typical star of Class Md. The Md spectrum closely resembles that of *o Ceti* at its last maximum, which is practically duplicated by that of many other long-period variables. A spectrogram in the red on November 9th shows that in this portion of the spectrum also, the chief features of R *Aquarii* bear a close resemblance to those of *o Ceti* as photographed on the preceding night. A bright Hα line is probably present tho not so well marked as in *o Ceti*.

On the first three plates the chief nebular lines N1 and N2, and $\lambda 4363$ are very conspicuous. On the later plates they are relatively less intense, as is also the hydrogen line Hβ. Meanwhile Hγ and especially Hδ had grown stronger. Thus at this time Hγ and Hδ should be classed with the Md spectrum and Hβ with the nebular lines, tho both sources may contribute partially to all three of the lines. It is difficult to judge of the absolute intensities of the nebular lines but it appears possible that they may have remained the same while the Md spectrum grew rapidly stronger with the increase in the star's brightness. This possibility, as well as the unusual character of the spectrum, raises the question whether the source of the nebular lines is actually closely associated with that of the Md spectrum. Some other evidence on this question is now available and it is hoped that much more can be added in the next few weeks. As observed at Mt. Wilson under fair conditions, the appearance of the object is stellar. An examination of it on November 1, by Professor Barnard, with the 40-inch telescope at Yerkes Observatory, did not disclose any true disk but showed certain focal peculiarities similar to those of novae in some of their earlier stages. Photographs by Mr. van Maanen on October 17th in the 80-ft. focus of the 60-inch with exposures of 30 sec., 3 min. and 15 min. do not show a nebular disk or any other striking peculiarity. On the spectrograms for which the star was held as nearly as possible on the center of the slit, the nebular lines do not extend farther from the center of the spectrum than do portions of the continuous spectrum (allowing for photographic effects). The radial velocities yielded by the nebular lines are about the same as those from the Md spectrum. An apparent tendency of the chief nebular lines N1 and N2 and Hβ to give algebraically greater velocities than the other bright lines, requires further investigation. To the above evidence for the identity of source of the nebular and the Md spectra may be added the consideration that if the nebular lines are derived from an object which is independent of the variable star but on the line joining it to the Earth, then such an object should have been discovered before this as a planetary nebula.

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[1] In the Harvard telegram and *Bulletin* No. 697 the word *nebulous* should be replaced by *nebular*. The lines are not nebulous but quite sharp with one-prism dispersion.

November 12, 1919. PAUL W. MERRILL.

NOVA OPHIUCHI

Two spectrograms of the new star found by Miss Mackie and announced in the *Harvard Bulletin* No. 696, were obtained on the nights of November 1st and 2nd. The first was taken with the 60-inch telescope and 7-inch camera and the second with the 100-inch telescope and 18-inch camera, using a single prism in both cases.. The star was apparently about the 9th magnitude and the exposure satisfactory.

The photograph taken with the 100-inch reflector and higher dispersion shows a large amount of detail which is yet to be examined. In general the spectrum is characteristic of new stars in the earlier stages. The bright bands of hydrogen and H and K of calcium are strong and well defined. There are many less prominent bright bands at λ5015, 4922, 4500-4700, 4233 and perhaps others more faint. The nebular bands have not appeared. A large number of strong and easily measured absorption lines, corresponding for the most part to those in the spectrum of *α Cygni*, appear from preliminary measures by Miss Burwell to be displaced 4.3 Angstroms to the violet.

The spectra are very similar to those of *Nova Aquilae* III taken on June 10 and 11, 1918, except in the width of the bright bands and the displacement of the absorption spectrum. The width of the bright bands is 8.5 at Hγ, and the displacement of the absorption lines is 4.3 Angstroms in *Nova Ophiuchi* as compared with a width of 46 Angstroms and a displacement of 23.6 Angstroms in *Nova Aquilae*. The bright bands are more numerous in *Nova Ophiuchi*.

W. S. ADAMS,
A. H. JOY.

THE SPECTRA OF TWO ALGOL VARIABLES OF LONG PERIOD

SX *Cassiopeiae* ($0^h5^m.5$; +54°20′: 1900) and RX *Cassiopeiae* ($2^h58^m.8$; +67°11′: 1900), with periods of 36.5 and 32.3 days, respectively, which have been suspected of belonging to later spectral classes than most of the Algol variables, have been observed by us for the determination of the absolute magnitude. The very low density of these stars as computed by Shapley[1] makes them of especial interest.

The spectrum of SX *Cassiopeiae* on five plates taken with the 100-inch telescope and 18-inch camera shows only one component and the range in velocity is about 75 kilometers. The spectrum is very much like that of *α Cygni* with many rather poorly defined enhanced lines and hydrogen lines of moderate strength. Some 40 lines have been measured and found to be identical in almost every case with those of *α Cygni*. The star will be followed further with a view to the investigation of its orbit.

The spectrum of RX *Cassiopeiae* is very similar to that of W *Serpentis*[2] which has heretofore been classed among the Cepheid variables but which also has a symmetrical light curve. The hydrogen lines Hβ, Hγ and Hδ are bright with the centers reversed. The red edges are stronger than the violet and Hβ is the strongest of the three lines. In other respects the spectrum seems to be of type G3. Two plates taken with the 60-inch telescope and 7-inch camera show a range of 11 kilometers from maximum to minimum of light. The spectrum of only one component is shown.

W. S. ADAMS,
A. H. JOY.

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[1] *Contributions from the Princeton Observatory*, No. 3, 1915.
[2] *P. A. S. P.* **30**, 306, 1918.

The Nebular Line 3869 in R Aquarii

After the discovery by Dr. P. W. Merrill of the presence of the bright nebular lines 5015, 4957 and 4363 A in the spectrum of the variable star R *Aquarii*, a spectrogram of this object was secured at Mount Hamilton, on November 3, 1919, with a one-prism spectrograph (linear dispersion at $H\gamma$ 1 mm. = 57 A) and the 36-inch refractor. The spectrogram, obtained with an exposure of three and a half hours, is of good density from 3868 to 5167 A. It shows, in addition to the nebular and hydrogen lines described in Dr. Merrill's paper in this number of the PUBLICATIONS, the bright nebular line, whose wave-length as determined by Wright,[1] from measures in the spectra of the gaseous nebulae, is 3868.9 A (Rowland).

Mount Hamilton, J. H. MOORE.
November 10, 1919.

Comments on the Occurrence of Nebular Lines in the Spectrum of R Aquarii

The discovery by Dr. Merrill of three of the brighter nebular lines in the spectrum of R *Aquarii*, an otherwise typical star of Class Md, is of the highest interest. It appears to be the first recorded instance of the association of peculiarly nebular lines with the spectrum of a red star, and is possibly of significance as establishing contact between these two classes of objects. The occurrence of the bright lines of hydrogen, and possibly of helium, in their spectra, has long been recognized as an outstanding peculiarity of the red variables, but the characteristically nebular lines have, until now, been looked for in vain. On the other hand there is abundant evidence connecting the gaseous nebulae with the white or "hot" stars, particularly with that extreme group, the Class O, or Wolf-Rayet stars. Since these, on the one hand, and the red variables, on the other, appear to have nothing else in common, it is going to be somewhat disconcerting if both groups are found to be related to the gaseous nebulae.

As the matter stands, there can be no question as to the presence of the four nebular lines: N_1, N_2, 4363, and 3869 A (the last of these having been observed by Dr. Moore, as stated elsewhere in this issue) in the spectrum of R *Aquarii*. Dr. Merrill's observations of the shortness of the nebular lines is confirmed by plates secured with the slitless spectrograph attached to the Crossley telescope of this observatory; in particular the N_1 image, which is the most suitable for observation, records, on these plates, as a point. Quite aside from this Dr. Merrill has brought out other arguments, which of themselves constitute ample proof that the nebular lines belong to the stellar spectrum. That much must be admitted. But there are certain differences in the habit of hydrogen in the Md stars, in the one case, and in those of Class O in the other, to which it seems worth while at this juncture to draw attention. In a Class O star the hydrogen is outstanding. When such an object is surrounded by a visible nebula the bright hydrogen lines reach out into it. In the Md stars, on the other hand, the glowing hydrogen is undoubtedly deep down in the star. Pickering's explanation of the absence (or weakness) of the $H\epsilon$ line of hydrogen, on the assumption that it is absorbed by the broad H calcium band, not only accounts satisfactorily for the missing hydrogen member, but shows, as well, that hydrogen radiation is emitted below the surface of the calcium absorbing layer, and while Pickering's hypothesis has been somewhat doubtfully accepted by certain astronomers for the very reason that it predicates an inversion of this character, it is altogether probable that it is correct, and furthermore, that the great irregularity which he reported in the intensities of some of the other lines in the series is also due to absorption in the atmosphere of the star; in particular, the weakness of $H\beta$ in *o Ceti* probably results from the fact that it lies within one of the lesser of titanium oxide bands which Professor Fowler has shown to be the cause of the dark flutings in Class M spectra.

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[1] *Pub. Lick. Obs.*, **13**, 242, 1919.

There is little question then that in the Class Md stars the glowing hydrogen lies at a very considerable depth in the stellar atmosphere; is the same true with respect to "nebulium"—using that much abused term in the widest and most general sense to cover the origin of all of the "unknown" nebular lines? It seems likely that it is. Among the many lines in the gaseous nebulae there are certain pairs or groups which appear to belong together. N_1 and N_2 form such a pair, and 3869 and 3967 A may be said, with almost an equal degree of certainty, to compose another. The former of these two lines is quite the brighter, but, as photographed with the single prism spectrograph attached to the 36-inch refractor, the intensity of the two is about equalized by the excess of absorption by the glass on the line of shorter wave-length, so that when photographed with that apparatus the two lines appear to be very nearly of the same strength, 3869 remaining a little the brighter, unless, as is the case in small objects, it is weakened by the chromatic aberration of the telescope. One of the lines is close to a hydrogen line, which interferes in some instances with the observation, but, as nearly as I have been able to determine, the intensity ratio of the two is practically constant in 37 out of the 40 nebulae that I have observed; in the remaining 3 neither of the lines in question is present. Furthermore the two lines have the same behavior in respect to distribution in those nebulae that are not homogeneous. They occurred together in the spectrum of Nova Persei No. 2. I think they are undoubtedly to be regarded as linked.[1]

Dr. Moore has photographed one of these lines (3869 A) in R *Aquarii*, but the other is not there, or at least, if it is, it is so feeble as to be indistinguishable in the dark line spectrum. Photographs with the slitless spectrograph confirm this observation. I cannot but regard it as significant that the position of the missing line lies very close to that of H calcium and falls within the spread of the calcium line in the spectrum of R *Aquarii.* It lies closer in fact to H than does Hε, the wave-lengths of the three lines being as follows:

	I. A.	
Nebular line.............	3967.51	
		−.97[*]
H calcium...............	3968.48	
		+1.74[*]
Hε hydrogen.............	3970.22	

Other things being equal, the conditions for absorption are therefore at least as good for the nebular line as for Hε. I cannot but regard it as probable that the absence, or weakness, of 3967 A is like that of Hε due to calcium absorption, and, if this construction be accepted, the origin of the line must, like that of Hε, be placed well within the calcium atmosphere.

With respect to N_1 and N_2 the conclusions are not so certain. Both of these lines lie within one of the strongest titanium oxide absorption bands in the spectrum, N_2 falling in the dense and nearly opaque head of the band. The fact that any light whatever gets thru at N_2 suggests that this line is not subject to the full absorptive effect of the titanium oxide atmosphere.[2] N_1 lies in a somewhat lighter part of the band, but is within a lesser and overlapping dark fluting, so the conditions for transparency are here a little, tho not very much, better than at N_2. Under the conditions any considerable submergence of nebulium, with respect to titanium oxide vapor, would result in a slight excess in the intensity of N_1 relatively to N_2. A number of experiments have been undertaken for the purpose of finding out whether such an effect exists. In one of them the spectrum of a gaseous nebula (N. G. C. 7027) was photographed over that of *α Herculis*, a class Mb star, which shows, of course, the titanium oxide flutings. One receives the impression that, with respect to N_2, the chief nebular line N_1 is somewhat stronger in the spectrum of R *Aquarii* than it is in this "synthetic" spectrum, but since the density function of a photographic plate varies with the wave-length, particularly in the blue-green, the matter can be settled definitely only on the basis of equal exposure intervals for star and nebula, which it has not yet been found practicable to make. Speaking generally, on the basis of the incomplete evidence at present available, it seems probable that the nebulium radiation is slightly affected by titanium oxide absorption, but is not subject to the full measure of extinction which that vapor exercises on the light of the star. If we assume that the pair 3869—3967A is emitted at the same level as N_1 and N_2 the level of nebulium, and probably of titanium oxide, is found to be below a very considerable portion of the star's calcium atmosphere. However, the last assumption is, perhaps, not justifiable; in the nebulae different groups of lines frequently have vastly different distributions, and the premise of equal levels of the origins of the two pairs may, perhaps, not reasonably be made.

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[1] See forthcoming *Pub. Lick Obs.*, **13**, part VI, chap. IV.

[*] In *o Ceti* and χ *Cygni*, typical Md stars, the bright hydrogen lines are displaced about −0.3 A with respect to the dark line system. If we assume this displacement to be normal for stars of their class the tabular residuals should be corrected by that amount, but even so the nebular line would remain the closer of the two.

The foregoing considerations are, of course, highly speculative, and are based on a number of assumptions, one, perhaps the most serious, of which has not been explicitly stated, namely, that an object like R *Aquarii* is a single and fairly homogeneous star. To what extent this and the other assumptions conform with the facts, we have at present no means of judging; still with all the uncertainty it seems worth while to draw attention to these apparent peculiarities in the behavior of particular lines in the spectra of the Md stars, not only because they indicate a difference in the conditions under which bright line radiation takes place in these stars on the one hand, and in some of the white stars and the nebulae, on the other, but also because they may prove suggestive in the study of the nature of the red variables. The observers of the Harvard College Observatory have noted numerous irregularities in the intensities of the members of the hydrogen series of bright lines, which undoubtedly will repay close study.

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[2] The assumption is here made that, under identical conditions, the nebular bright lines would be subject to the same absorption by the titanium oxide as that which the latter exerts on the continuous spectrum. The bright lines are probably sufficiently broad, and the lines of the flutings close enough together, to insure this being the case.

I wish to acknowledge my indebtedness to Dr. Merrill for the use of a print of the spectrum of R *Aquarii* and to Dr. Moore for the privilege of examining the plate secured by him.

November, 1919. W. H. WRIGHT.

SPECTROSCOPIC OBSERVATIONS OF TWO RECENTLY DISCOVERED NOVAE

The two new stars recently announced by Professor Bailey of the Harvard College Observatory as having been discovered there by Miss Mackie have been examined spectroscopically at the Lick Observatory.

Nova Sagittae, R.A. = $20^h 3^m.1$; Dec. = $+17^\circ.6$ (1900) *H.C.O. Circular* No. 219. This star is reported to have appeared as a nova of 7.2 magnitude in 1913. It is now relatively faint and is described as closely following a 14.5 magnitude star. Preliminary to a spectroscopic observation of its spectrum a finding plate was kindly photographed by Dr. Curtis with the Crossley reflecting telescope. On this plate the nova is much brighter than the companion referred to above.

Two spectrograms have been secured with the small slitless spectrograph attached to the Crossley reflector. The dispersion is very low and the record faint but the general character of the spectrum is apparent. It is continuous and lies chiefly in the ultraviolet. The intensity is pretty uniform thruout its length. While no bright nor dark bands are visible in the spectrum the possibility of their existence is not precluded; the dispersion used is very weak and the observation can be taken as establishing only the general nature of the radiation.

The stellar image on Dr. Curtis's plates is stronger than one would be led to expect from the Harvard description of it; it is particularly intense on a Seed No. 23 plate, as compared with a No. 30. This is doubtless to be accounted for by the spectral peculiarity of the star. Its light lies very largely in a region to which glass is only partially transparent, but which is within the range of a reflector. Since the Harvard photographs were made with a refractor and those at Mount Hamilton with a reflecting telescope the difference in intensity is readily explained. The observations furnish an instance in which the so-called color-index of a star depends upon the nature of the apparatus with which the photograph is made.

Nova Ophiuchi R.A. = $18^h 9^m.5$; Dec. = + 11°.6 (1900). The history of this star is sketched in the Harvard College *Bulletin* No. 696. Notification of its discovery reached the Observatory on October 30th, and its spectrum has since then been observed as systematically as the somewhat unfavorable weather has permitted. The star is reported to have been at magnitude 7.5 on September 13th and, with striking fluctuations in brightness, to have declined to magnitude 9.5 in October. The first observation was secured with the large Crossley slitless spectrograph on October 30th, and showed the bright bands of hydrogen and enhanced iron characteristic of the post-maximum nova spectrum. The spectrum resembled that of *Nova Geminorum* No. 2 as it appeared on March 18, 1912, a few days after maximum. The bands in the present nova were, however, very much narrower at that time. The star increased in brightness reaching a magnitude of about 7¼ on November 5th; it therefore achieved a second maximum comparable with its first. Since then it has fallen off in brightness and on November 13th was estimated to be of about 8¾ magnitude. These estimates of brightness are very rough and are based on the Durchmusterung magnitudes of a few stars in the finder field.

The observations after that of October 30th, referred to above, were made with a slit spectrograph and are therefore not strictly comparable with it, but the rise in brilliancy of the star appears to have been marked by an increase in the strength of the continuous spectrum relatively to the bright bands, and its decline was certainly due to a corresponding subsidence of the continuous spectrum. At the time of maximum many of the bright bands were all but obliterated by the strong continuous radiation. With the fading of the star the emission bands in its spectrum broadened out and are now of a width comparable with those in the spectra of previous novae. The emission bands, particularly those of hydrogen, have at all times been accompanied by the usual dark absorption lines, displaced toward the violet. The present appearance of the spectrum is very much like that of *Nova Geminorum* on March 18, 1912, the date previously referred to.

The continuous spectrum which characterized the rise to maximum contained numerous strong dark lines, and furnishes a most remarkable example of what may perhaps be called the typical dark line nova spectrum. The resemblance to the spectrum of *a Cygni*, remarked in previous novae by other observers, is more striking than was the case with *Nova Aquilae*, or in fact with any nova that has come under my observation. The stellar lines are, as usual, displaced in the nova to correspond with the dark hydrogen lines. The line absorption overlies the hydrogen emission bands.

The dark line spectrum has, in previous novae, characterized an early period, an interval close to the outbreak of the star, and has been followed by the so-called "bright-band" stage. The reversion to the earlier type, in the present instance, coincident with the rise to second maximum suggests that the forces which act to produce a nova were called into play a second time.

The spectrum of this star offers the possibility of determining with a great degree of certainty the constituents of the atmospheres of new stars. It ranks in interest with those of the brighter novae of recent years.

W. H. Wright.

Comet Notes

The Brorsen-Metcalf comet, known earlier as Metcalf's first comet of 1919, passed perihelion on October 16th. It is now in the morning sky, having passed the Sun, and it is moving southward. By the first of November it was difficult for northern observers, because of the nearness to the Sun, and the southern declination. Two observations were secured, however, at the Lick Observatory on November 3rd and 4th.

These two positions indicate that the elements given in *Lick Observatory Bulletin* No. 324 are quite close to the truth, for the observations are represented within the numerical accuracy of the ephemeris. It appears that the period of 72.1 years will not be much changed by any increase in observational data. In this connection an announcement emanating from the Copenhagen computers is of interest. They have obtained an orbit with a period of only 42 years, so that it seemed likely that there had been two revolutions since 1847, instead of but one. Inasmuch as this orbit shows considerable deviation from observation on November 3rd and 4th, the correctness of this short period seems very doubtful. Not improbably the Copenhagen orbit of 42-year period suffers from some inaccuracy of observation. The orbit by the same computers from different observations, and with a shorter arc, with period assumed as 72.095 years, is quite close to the one by the writer, and it represents the observations better than does the unconditioned 42-year ellipse. A characteristic feature of the orbits for comets of long period derived from observations extending over but one apparition is the indeterminateness of the calculated periods. A parabolic orbit is found in the case of this comet to represent observations over a considerable interval with an accuracy not much less than that of the conditioned ellipse. This comet affords a good example of the manner in which the accuracy of the elements and consequently of the ephemeris may be increased, when moderate time intervals are used, by assuming an approximately known period.

On October 25th another comet was discovered in Japan by Sasaki of the Kyoto Observatory. The cabled announcement was delayed some days, and by the time it reached American observers the Moon had moved close to the given position. On November 9th the Moon had moved away sufficiently and the object was found by Fayet at Nice. It was first observed at Mt. Hamilton on November 12th. It is diffuse, condensed in the center, with the suggestion of a nucleus. Schaumasse has identified this comet with Finlay's periodic comet, one of short period which has been observed repeatedly at returns since 1886. The identification is without doubt correct, for while the observed position differs by almost three hours and a half in right ascension, and eleven degrees in declination from the position calculated from Fayet's elements for 1913, an empirical change of the perihelion time of only eight days, to October 15th, results in a reasonably close agreement of theory and observation. Such a change is justifiable, for the difference may easily be accounted for by the action of planetary perturbations. It is to be expected that further calculation will confirm the identification.[1] Assuming an identity with Finlay's comet, it is found that the object is quite close to the Earth (on November 12th) astronomically speaking, for it is but a fifth of an astronomical unit, or roughly 19,000,000 miles away.

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[1] November 18th. Elements for this comet, computed by Professor Crawford and Miss Fairfield and Miss Cummings at the Students Observatory, Berkeley, have just been received. As was anticipated, these elements place the identity of this object and Finlay's periodic comet beyond question. The revolution period is 6.1 years and the object belongs to the well-known *Jupiter* comet family.

On October 31st announcement was made thru the Harvard College Observatory that a comet was observed by Fayet on October 29th. This is supposed to be the periodic comet first found by Schaumasse in 1911, the return of which has been expected. There is a larger discrepancy of the observed position from the ephemeris by Fayet and Schaumasse than would naturally be anticipated. There is but the one observation by Fayet so far at hand. The comet is difficult to observe, for it is low in the morning sky, near the Sun, and quite faint.

November 17, 1919. H. M. JEFFERS.

NEW INFRA-RED LINES IN THE SOLAR PROMINENCE SPECTRUM

The solar prominence spectrum was photographed in the region 6500A to 9200A. The apparatus used was the 36-inch refractor and the grating spectrograph described by Campbell and Albrecht in *Lick Observatory Bulletin*, **6**, 11, 1910. The second order of the grating was used thruout, the scale being about 10.5A per millimeter. The resolving power was in the neighborhood of 90,000. The photographic plates were sensitized by means of dicyanin kindly furnished by the Bureau of Chemistry (Washington).

In the visual region only the well-known bright lines hydrogen Hα, helium D_3, and helium 7065A were recorded. The known helium line at 6678A was too faint to be photographed in the half-dozen prominences which were observed. The line at 7065A, on the other hand, was always found to be very strong, showing the same distribution of intensity as Hα and D_3. The different behavior of these two helium lines is of considerable interest and would seem to deserve further study, in spite of the large number of visual observations which have been made on them. The line at 7065A has usually been characterized as "weak" by visual observers, but photographically with dicyanin it is strong, rivalling D_3.

In the region of wave-lengths longer than 7065A no prominence line was found until the calcium triple beginning at 8498A was reached. Of these three lines, the second, at 8542A, is always easily photographed; the third, at 8662A, is usually strong enough to be observed in the prominences; while the first, at 8498 A, always shows bright borders, but is much the faintest of the three in the prominences.

Dr. P. W. Merrill called my attention to the fact that these three lines in the laboratory spectrum of calcium are strong in the spark, and therefore might be expected to show in prominences. Perhaps the converse is true, that the magnesium line at 8807 A, which shows bright borders at the edge of the Sun, will be found to be a spark line.

Beyond 8807 A no line was observed in the prominences and none was found to give certain indications of bright borders at the Sun's limb.

The intensity of the sky spectrum relative to that of the solar disk falls off quite rapidly with increasing wave-length. This phenomenon probably follows Rayleigh's law, according to which the scattering of light by the molecules of the Earth's atmosphere varies inversely as the fourth power of the wave-length. The low intensity of the scattered light in the deep red and infra-red should facilitate the observation of any strong coronal lines that might be present. However, no such lines were found. The solar image is noticeably steadier in the infra-red than it is in the yellow-green.

Mt. Hamilton, Calif., KEIVIN BURNS.
November 17, 1919.

THE Hα LINE IN *o Ceti*

During the recent maximum of *o Ceti*, which occurred early in August, its spectrum was photographed in the region 4800 to 6700A. The first spectrogram was obtained on July 22nd with the one-prism spectrograph set for minimum deviation and focus at D. On examining the plate it was seen that Hα and Hβ were both bright and that Hα was strongly displaced toward the violet, while Hβ was shifted toward the red with reference to the hydrogen comparison lines. Since the displacement of Hβ was the same as that ordinarily shown by the hydrogen lines in *o Ceti*, it was considered that Hα presented a peculiarity which should be investigated further. Accordingly plates were secured on July 25th and September 16th with the three-prism spectrograph set for minimum deviation at D. On both plates the Hα line is well shown. A plate was also obtained on August 6th with the one-prism spectrograph set for Hγ. This plate shows the bright lines Hβ, Hγ, Hδ, Hζ and Hη. The displacements of the hydrogen lines on these four plates have been measured and are given below. They are with reference to the absorption spectrum of the star for which a radial velocity of +62.1 km. has been used. The sign + indicates that the line is displaced toward the violet.

Date	Spectrograph	Displacement in Angstroms					
		Hα	Hβ	Hγ	Hδ	Hζ	Hη
1919 July 22	I Prism D	+2.1	+0.1				
July 25	III Prism D	+1.32					
Aug. 6	I Prism Hγ		+0.11	+0.20	+0.22	+0.08	+0.16
Sept. 16	III Prism D	+1.09					

The Hα displacements shown in the table might seem to indicate a progressive change but this is probably due to accidental errors of measurement. This is rendered more probable by the fact that a plate taken with the one-prism D spectrograph on November 3rd, when compared on the Hartmann measuring engine with the plate of July 22nd shows no change in the position of Hα between these two dates.

It might be suggested that in view of the occurrence of other emission lines than those of hydrogen in the spectrum of *o Ceti*, the line above referred to as Hα is really some other line and that Hα is very weak or absent. This is not very probable, however, because all the other hydrogen lines as far as Hρ have been observed during the recent maximum and it would be about as difficult to account for the absence of Hα as for its anomalous displacement. In addition, no other bright lines have been observed in the visual region, and it is quite unlikely that the only one should be of such great intensity and so near the normal position of Hα as the line here discussed.

A more complete discussion of both the visual and the ultraviolet spectrum of *o Ceti* will be published in the near future.

C. D. SHANE.

GENERAL NOTES

The Einstein Effect.—In a note on page 114 of the present volume of these PUBLICATIONS, attention was called to two expeditions that were to be sent out from Great Britain to observe the total eclipse of the Sun on May 29, 1919. The chief object of both expeditions, as the note referred to stated, was to test the Einstein theory of relativity in so far as it predicted the effect of gravity upon light radiations. According to press dispatches, announcement was made at a joint meeting of the Royal Society and the Royal Astronomical Society, held in London on November 7th, that the expedition to Brazil had been successful, and that the photographs obtained fully demonstrated the correctness of Einstein's theory. In other words, they proved that rays of light from stars in passing close to the Sun's limb at the instant of eclipse were deflected by the Sun's gravitational pull to the degree predicted by the theory. This is a result of such fundamental importance that confirmation is obviously most desirable, and it is stated that British astronomers, with this idea in mind, are already giving consideration to favorable eclipses which will occur in the next two or three years.

Preliminary Parallax of Nova Aquilae III.—Prof. C. P. Olivier has published (in *Astron. Jour.* No. 757) an approximate value for the parallax of the new star which appeared suddenly on June 8, 1918, and for a few hours was the brightest star in the sky. He finds for the relative parallax the value +0″.004, "or, adding as usual +0″.005, the assumed average value for comparison stars of 9th magnitude, to turn this into absolute parallax," the absolute parallax +0″.009 corresponding to a distance of about 360 light years. Professor Olivier emphasizes the fact that this value is only approximate and states that the final value from the plates taken at the McCormick Observatory will not be computed until data for at least two more epochs are available. It is of interest to note that Olivier's value of the parallax is very much smaller than the preliminary value (0″.060) obtained at Mount Wilson by Messrs. van Maanen and Sanford, which was published in our August number (page 234). Our knowledge of the distance of the nova and of its brilliance at maximum is obviously still quite unsatisfactory. If we accept the larger parallax value, the star is about

54 light years distant and, at maximum, was about 1700 times as brilliant (absolute brightness) as our Sun; taking the smaller value, the distance must be increased about seven-fold, and the brilliance nearly fifty-fold!

A Bright Star With a Very Distant Faint Companion.—Dr. Robert Trumpler[1] has added another example of a pair of stars apparently widely separated which are moving together thru space. In determining the parallax of the star B.D.+7°2690 (6.32 visual magnitude) at the Allegheny Observatory, he found that the 10th magnitude star B.D.+7°2692, which is more than eight minutes of arc distant from it, has the same large proper motion and the same parallax. There is thus no question but that the two stars are physically connected, tho the projection of the linear distance between them amounts to no less than 13,200 astronomical units. If we were to assume that the two stars were revolving about a common center in a circular orbit, the time required for a single revolution would be measured in hundreds of thousands of years. Orbital motion in such pairs is open to very serious question, to say the least.

Professor Annibale Riccò.—It is with great regret that we record the death of Professor Annibali Riccò, director of the Observatory of Catania, Italy, and known particularly for his researches in solar physics. Professor Riccò was one of the vice-presidents of the recently established International Astronomical Union.

A note in *Science* for November 28, received as this number is going to press, states that Dr. Frank Schlesinger, director of the Allegheny Observatory, has been appointed director of Yale University Observatory. It is understood, tho not stated in *Science*, that Yale University is to build a modern observatory in the near future.

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[1] *Astron. Jour*, **32**, 95, 1919.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON NOVEMBER 29, 1919, AT 2.00 P. M.

There were present President Hodghead and Directors Aitken, Cushing, Costa, Benfield and Richardson. The proxy of Director Campbell was held by Aitken and that of Director Hale by Richardson.

The minutes of the last meeting were read and approved.

The following new members were elected:

PROF. ANTONIO ABETTI,
DR. A. E. BOSTWICK,
DR. HENRI CHRETIEN,
MR. D. P. BISSELL,
MR. A. O. RHEA,
MR. KENNETH KELLY,
COMTE A. DE LA BAUME PLUVINEL,
DR. V. V. RAMANAN,
MR. S. H. WESTFALL,
DR. WM. M. COLLINS.
The Phoenix Public Library, Ariz.
Perkins Observatory of Wesleyan University.

The committee appointed at last meeting to report on the advisability of purchasing a lantern asked for more time, which was granted.

A committee consisting of Hodghead and Cushing, to report on proposed changes in the Statutes for the bestowal of the Bruce Medal asked for more time, which was granted.

The president appointed Dr. R. T. Crawford, Frank V. Cornish and A. L. Black as the committee to make nominations for Board of Directors and Publication Committee at the annual meeting of the Society in January next.

The president appointed C. S. Cushing, J. D. Galloway and B. L. Hodghead as Auditing Committee to report at the annual meeting in January.

The special business of the meeting, which was to consider the award of the Bruce Gold Medal for the year 1919, was then taken up. Nominations from the Directors of Harvard, Yerkes, Lick, Greenwich and Cordoba Observatories were read by the secretary. Paris was not heard from. After careful consideration of names submitted, the award was finally made by unanimous vote of the six Directors present, together with those of Campbell and Hale by proxy, making a total consenting vote of eight. Announcement of the award made will be given out after the formal acceptance by the medalist selected has been received.

Adjourned.

D. S. RICHARDSON, *Secretary.*

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD AT THE STUDENTS' OBSERVATORY IN BERKELEY, ON SATURDAY, NOVEMBER 29, 1919, AT 8.00 P. M.

It was a stormy night, but that fact did not deter a very appreciative audience from coming out to hear the lecture of Dr. Robert G. Aitken, of Lick Observatory, whose subject was, "Island Universes; What We Know About Them."

Some very beautiful lantern slides were shown.

The lecture was preceded by brief remarks from President Hodghead, outlining the activities of the Society during the past year. Among other guests present, the members of the Society were pleased to note the presence of Dr. Shinzo Shinjo, the Director of the Imperial Astronomical Observatory of Kyoto, Japan.

Adjourned.

OFFICERS OF THE SOCIETY.

BEVERLY L. HODGHEAD	*President*
R. G. AITKEN	*First Vice-President*
MRS. ISAAC ROBERTS	*Second Vice-President*
J. COSTA	*Third Vice-President*
D. S. RICHARDSON	*Secretary and Treasurer*

Board of Directors—C. S. CUSHING, B. L. HODGHEAD, A. H. MARKWART, D. S. RICHARDSON, J. COSTA, MRS. ISAAC ROBERTS, BERNARD BENFIELD, R. G. AITKEN, J. C. CEBRIAN, G. E. HALE, W. W. CAMPBELL.

Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
Finance Committee—C. S. CUSHING, W. H. CROCKER, A. H. MARKWART.
Library Committee—D. S. RICHARDSON, F. V. CORNISH, MRS. ISAAC ROBERTS.
Donohoe Comet-Medal Committee—W. W. CAMPBELL, JOSEPH H. MOORE, STURLA EINARSSON.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

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Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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THE ADOLFO STAHL LECTURES IN ASTRONOMY

This volume contains the twelve Adolfo Stahl Lectures which were delivered in San Francisco in the seasons 1916-17 and 1917-18 under the auspices of the Astronomical Society of the Pacific by members of the staffs of the Lick Observatory, the Mount Wilson Solar Observatory, and the Students Observatory at Berkeley. They cover a wide range of topics, the endeavor being to present in non-technical language, but without sensationalism, some of the more recent results of studies of the Sun, the Moon, the Comets, the Solar System in general, the Stars and the Nebulae. One lecture, also, treats of the methods of astronomical discovery; another of recent progress in the study of motions in the solar system; still another, of the important epochs in the development of astronomy; and the volume concludes with a description of the great 100-Inch Reflector on Mount Wilson, the most powerful telescope in the world.

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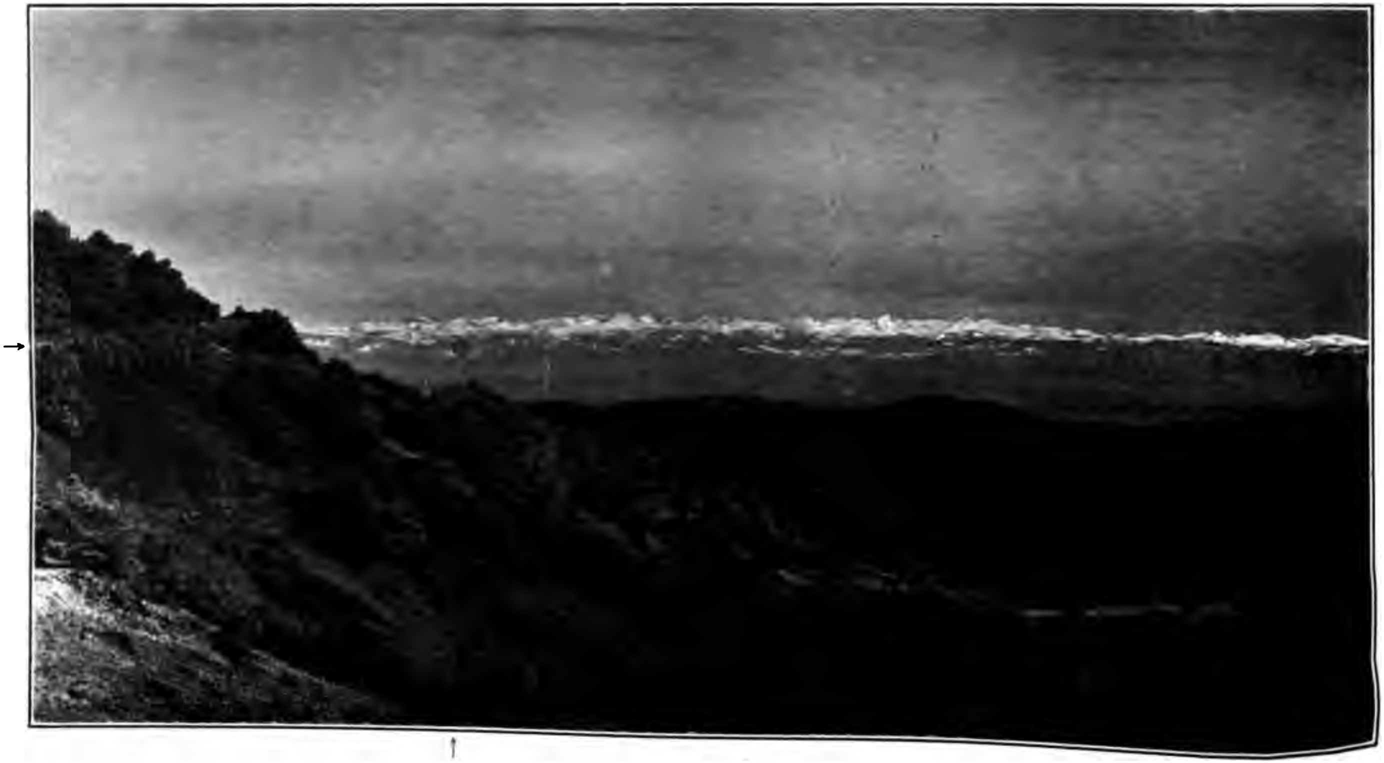

THE SIERRA NEVADA MOUNTAINS AND THE YOSEMITE VALLEY
Photographed from Mount Hamilton on January 25, 1920. See note on page 69. The dark object just in the snow line opposite the arrows in the margin is the north face of the Half-Dome, Yosemite Valley, 120 miles from Mt. Hamilton.

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EXCHANGES

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Revista de la Sociedad Astronómica de España y America, Barcelona, Spain.

Mr. C. A. Chant, Royal Astronomical Society of Canada, Toronto, Can.

Observatorio Astronómico de Cartuja, Granada, Spain.

Gazette Astronomique, Société d'Astronomie d'Auvers, 29 Stamford St., London, S. E., England.

Astrophysical Journal, Yerkes Observatory, Williams Bay, Wisconsin.

Popular Astronomy, Northfield, Minn.

The Editors of the Observatory, The Royal Observatory, Greenwich, England.

The Royal Observatory, Greenwich, England.

The Hon. Librarian, British Astronomical Association, Sion College, Victoria Embankment, London, E. C. 4, England.

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Journal Astronomique, Observatoire de Lille, Hem, France.

Astronomia Populare, Palazo Madama, Turin, Italy.

Società Astronomica Italiana, Rue Maria Vittoria 23, Turin, Italy.

Monthly Notices, Royal Astronomical Society, London, England.

American Mathematical Society, 501 West 116th St., New York, N. Y.

Società degli Spettroscopisti Italiani, Catania, Italy.

Sociedad Cientifica "Antonio Alzate," City of Mexico, Mexico.

Solar Observatory, Mount Wilson, via Pasadena, Cal.

American Philosophical Society, 105 South Fifth St., Philadelphia, Pa.

Harvard College Observatory, Cambridge, Mass.

The Monthly Evening Star Map, 150 Nassau St., New York, N. Y.

The Astronomical Herald, Tokyo, Japan.

Publication of Pomona College, Claremont, Cal.

The Astronomical Journal, Dudley Observatory, Albany, N. Y.

Journal of the Royal Astronomical Society of Canada, 198 College St., Toronto, Canada.

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Journal de Physique, No. 1 Victor Cousin, Paris, France.

Sociedad Astronómica, via Diagonal 442-3 Ia, Barcelona, Spain.

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PROGRESS IN PHOTOGRAPHY RESULTING FROM THE WAR

By Paul W. Merrill

If the human energy and material wealth which were expended in the great war could have been devoted to the prosecution of scientific research how valuable the results would now be; how different from the actual results of devastation and want! What splendid applications of scientific knowledge to practical problems and what improvements in many technical processes would surely have been accomplished along many lines; and who knows to what extent the outlook on the great mysteries of nature might have been widened—to the future benefit of mankind!

Aside from the irreparable loss of life it is perhaps an open question whether scientific work has on the whole been injured or assisted by the war. Much research, of course, had to stop on account of the absence of investigators from their laboratories and offices. On the other hand the government, which usually regards such work as an unnecessary luxury and gives but a pittance to its prosecution, under the stress of a great emergency acknowledged its value and supplied it with funds as never before. Accordingly, certain kinds of research were vigorously pushed and were developed far more rapidly under war conditions than they would have been otherwise. The losses of the war are irretrievable and it is therefore all the more important to make the most of anything on the other side of the account. Promising novelties should be further developed and new methods of general and permanent value should be made widely available. That there is considerable material of this kind has been well known to many who were in touch with the scientific and technical aspects of the war; and this is now being made obvious by the contents of current technical periodicals. The military authorities seem to be taking a broad and wise view of the question and are allowing the publication of a great deal of material of general interest.

Photographic methods were employed in the recent war to an extent never known before in military history. This was brought about by the wonderful development of airplanes, which allowed the military photographer a choice of strategic viewpoints heretofore existing only in imagination and speculation. Before the war photography had apparently played a very minor part in the military intelligence service. In any event the United States was even less well prepared in military photography than it was in many other of the technical phases of modern warfare. The navy accomplished a little good work in aerial photography early in the war, which, however, did not become widely known. The faulty organization and mismanagement in that portion of the Signal Corps devoted to the production and operation of aircraft prevented rapid development of the art and science of military photography in the army. The inefficiency was probably due, not so much to the gross incapacity of the officers as to conditions which required the development, in a time really too short for the purpose, of an enormous organization dealing with a subject in which there was scarcely a single competent expert in the whole country. The new officers, doing the best they could under trying conditions, were hampered by the organization and methods of the war department, which are not at all adapted to the rapid development of innovations. Unfortunately also there were some officers who seemed unable to grasp the essential requirements of the situation; who gave no heed to the query "what *can* be done?" but were only concerned with "what *has* been done?" Obviously this policy was suicidal as applied to such a problem as that of aerial photography in the great war. These men retarded photographic progress considerably, but before the armistice was signed much substantial work was under way which would have been of great assistance at the front a little later.

The European nations also had been rather slow about advancing photographic technique, but actual contact with the fighting had pointed out certain egregious mistakes made early in the war and good progress was being made toward the last. However, it is not the purpose of this article to relate the photographic history of the war but to set forth some of the wartime developments in photography which seem likely to be of permanent interest to photographers, and, in particular, to those who make use of photography as an aid to scientific research.

Improvements in photographic emulsions are of vital importance to the physicist and especially to the astronomer, since many objects to be photographed are faint and available exposure times are limited. A large portion of the work is spectroscopic in character, and dry plates are required which are sensitive not only to the whole of the visible spectrum, but to a considerable range of invisible wave-lengths beyond either end. In a great many important instances scientific work is limited by the characteristics of available photographic emulsions.

It was found early in the war that aerial photographs, except those taken straight down (called verticals) from low altitudes, were adversely affected by the haziness of the air, and that satisfactory pictures from altitudes above 8000 to 10,000 feet, or long distance "obliques" at any altitude, seemed impossible even on clear days. Of course these views were just the ones of greatest value for military purposes. The cause of the difficulty and the remedy for it were readily suggested from spectroscopic principles. The haze, which makes the image of the ground indistinct, is due to sunlight scattered toward the lens by particles lying in the cone joining it to the ground. This scattered light is rich in the short wave-lengths; it is even more detrimental to the ordinary photograph than to the eye, so that the use of the longest wave-lengths possible was clearly indicated. At first orthochromatic or yellow-sensitive plates were used with good results, but before long it was apparent that for photographs from high altitudes, and especially for obliques, red-sensitive plates would be required.

This knowledge led to considerable research on color sensitive emulsions. The only practical method known at present, by which photographic emulsions can be made sensitive to the longer wave-lengths (yellow, red, and infra-red light), involves the use of certain synthetic dyes. These dyes may be mixed in the emulsion before it is coated on the plates, or they may be applied to the plates after manufacture by immersing them in solutions containing the dyes.

Commercial color-sensitive plates have long been made by mixing sensitizers in the emulsion. In an attempt to produce panchromatic plates for military purposes at least three firms succeeded in improving their previous emulsions. The most notable success of all was by the English firm of Ilford Limited. Their new pan-chromatic plate is the best of its kind which has yet been produced. Its speed to red light is especially great, and its other properties of contrast and freedom from fog make it as a whole a remarkably fine plate, that should prove very useful for many purposes including photography of the spectrum. The special technique employed in obtaining these excellent results appears to be quite new and a real step in advance of previous processes. It consists of a method of stimulating the sensitizing powers of certain dyes of the pinacyanol class. This may be done by the use of ammonia, but plates so prepared are liable to fog and will not keep. Another method, involving *auramine*, a yellow dye of the coal-tar group, as an auxiliary agent, was discovered in the Ilford laboratories by F. F. Renwick and O. Bloch; it gives increased speed and at the same time yields clean-working and reasonably stable plates. Plates prepared by this method were produced in large quantities for war photography and are now on the market under the name Ilford Special Rapid Panchromatic. This emulsion has a fairly uniform sensitivity from the ultra-violet to the extreme red. With strong exposures the action will extend as far as 7800A in the infra-red; in ordinary work it may be considered to cease at 7200A. The plate as now made is a compromise between an increase of speed and red-sensitiveness on the one hand, and ease of working and keeping properties on the other. It can be made much faster, but then becomes liable to fog and will not keep; hence it is not suited to commercial exploitation. For purposes of aerial photography in the war this plate was developed to a point where exposures thru a spectroscopically pure red filter could be obtained in one one-hundredth of a second.

The Eastman Kodak Company also produced a somewhat similar plate that was a decided improvement on the previous Wratten panchromatic emulsions. While this plate is not yet on the market, the company has offered its services in the production of special color-sensitive plates for experimental and scientific purposes, and has been very generous in responding to requests that have been sent to it. It manufactured and distributed a large number of experimental emulsions for war work.

The Cramer Dry Plate Company produced a fine red-sensitive plate of a different type. This emulsion is slower, but has more contrast, is finer grained, and works beautifully clean. Moreover, they succeeded in hardening the film in such a way that the usual hot-weather troubles of softening and frilling are practically eliminated. The emulsion may be used under conditions which are quite impossible for most emulsions; for example, development and washing at high temperatures. This property might prove of great value in the tropics, and on expeditions where the ordinary conveniences are not available. The plate, which is for sale under the name Cramer Spectrum Process, was specially prepared during the war for military use.

A laboratory method of producing color-sensitive plates is to soak ordinary plates in solutions of the sensitizing dyes. The method is not difficult, as it requires only the usual dark-room facilities. Moreover, for regions of the spectrum of greater wave-length than about 5900, plates so prepared can be made more rapid than any commercial brand (with the possible exception of the new Ilford plate at certain wave-lengths). Plates treated in this way are known as bathed or stained plates. The general characteristics of a considerable number of photographic dyes have been known for some time, largely thru the work of Eder and his associates. A number of years ago an extensive program, involving careful experimentation on the technique of bathing, was carried out by R. James Wallace[1], then connected with the Yerkes Observatory. He found that the best results were obtained by using the dye in a dilute water and alcohol solution containing a small amount of ammonia. He recommended rapid drying to produce the most sensitive plates and used a rinse in pure alcohol after the staining bath. A good deal of experimentation since that time has shown the wisdom of these details of manipulation, and no essential improvements have as yet been introduced. The use of water and alcohol is a compromise between different considerations. Other things being equal a water bath would probably produce faster plates, but the drying cannot be made rapid enough except under especially favorable conditions. Moreover the dyes flocculate very quickly in a water solution upon the introduction of ammonia, so that such a bath is inconvenient to use and with some dyes nearly impossible. An alcohol solution best holds the dye in suspension (it is a question whether or not true solution occurs), and allows the drying to take place much quicker, but alcohol so hardens the gelatine film that the dye will not enter it properly. Hence an alcohol and water bath, followed by an alcohol rinse, has been found the most favorable. War work at the Bureau of Standards showed that it was possible to use several other organic solvents instead of ethyl alcohol, but none of these was found superior to it. Since water and alcohol give slightly different spectro-sensitivity curves, quite a number of other dye solvents were tried in the hope that they might give still better sensitivities; but all such solvents, when diluted with water (in order to soften the film), seem to give practically the same curves. Excellent results were obtained with acetone and water, and fair results with methyl alcohol and a few other substances. Only those solvents which were not decomposed by the action of ammonia were tried.

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[1] *Ap. Jour.*, **26**, 299. 1907.

Presence of ammonia is found to be an essential part of the process if the greatest sensitivity is required. A number of different methods of applying the ammonia have been tried, but the Wallace process was found the most successful of all. One method, which led to interesting results in another connection, may be mentioned here. It was surmised that the dyed plates would keep better if the ammonia were omitted from the dye bath, and that the increase in speed might be obtained by a subsequent ammoniating bath. This was found to be the case, but the method was not very satisfactory; the final result was not equal to that produced by the regular Wallace method, the plates showed more defects and two separate soakings and dryings were involved instead of one. However, the increase in speed of the dyed plates upon subsequent ammoniation suggested that possibly commercial panchromatic plates could be hypersensitized by treatment with ammonia. This was tried in the spring of 1918 at the Bureau of Standards by the writer, with the assistance of Miss Barton, with excellent results. All of the plates tested had the red sensitivity enhanced, some of them to an astonishing degree. The development of this method was taken up as a war problem by Drs. Kiess and Burka of the Bureau of Standards. As the result of a large number of systematic tests the following procedure was recommended:

> Soak the plates for four minutes in a bath composed of water 75 parts, ethyl alcohol 25 parts, concentrated ammonia 3 to 4 parts. Dry rapidly in a current of air. To make certain of rapid drying the plates may be rinsed in pure ethyl alcohol for 15 seconds immediately after the ammonia bath.

The work has been further extended by Mr. Burka and is described in his doctor's thesis presented to Johns Hopkins University in 1919. The thesis will be published in the Proceedings of the Franklin Institute for January, 1920.

Unfortunately the hypersensitized plates will remain in good condition for a limited time only—a few weeks at the most. Nevertheless the original speed of the plates is so greatly increased, especially in the red, that the process should be a boon to spectroscopists and others who desire very rapid-color sensitive plates, and who are not prepared to sensitize ordinary emulsions by the use of dyes. It appears to be applicable to those emulsions in which the color sensitivity is gained by means of certain groups of the quinolinium dyes. This includes all panchromatic plates, and certain brands of orthochromatic plates.[2]

As mentioned above, certain synthetic dyes, known as sensitizing or photographic dyes, are essential to the production of emulsions capable of being affected by yellow and red light. Previous to the war practically the sole source of the most important of these dyes, with the exception of erythrosin, was the firm of Meister Lucius and Brüning, Hoechst am Main. They made a large number of dyes, including pinaverdol, pinacyanol, orthocrome T, pinachrome, pinacyanol blue, pinachrome violet, pinachrome blue, dicyanin, and dicyanin A. With the shutting off of this source of supply attempts were made to produce the more important dyes in England and in this country.

In the United States the production of photosensitizing dyes was taken up by the Chemical Section of the Science and Research Division of the Bureau of Aircraft Production, under the direction of Dr. H. D. Gibbs. The problem of the synthesis of the various dyes required for the preparation of plates used in aerial photography was assigned to Dr. Louis E. Wise of the Bureau of Chemistry, Department of Agriculture. In its solution the Bureau of Chemistry coöperated actively. The work was carried out in their laboratories by their chemists, assisted by men with chemical training assigned to them from the military service. Closely associated with Dr. Wise in the dye investigations was Dr. Elliot Q. Adams. These men deserve great credit for the excellent results which have been achieved. The first phase of the work was undertaken to find which particular quinoline derivatives were the ones to be used in making pinaverdol and pinacyanol. In a few weeks they had succeeded in producing pinaverdol, and both the iodide and chloride of pinacyanol. Important improvements were made in the German methods of preparing some of the essential intermediate compounds.

The chemical complexity of these compounds may be inferred from their formidable designations. A few samples follow: toluquinaldine methyl iodide; p-toluidine hydrochloride; alpha, gamma-di-methylquinolinium alkyl halides. The structure of pinaverdol is indicated by "1, 1′, 6′-trimethyl-iso-cyanine iodide."

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[2] For further information on this method of hypersensitizing see *Circular of the U. S. Bureau of Standards*, "Color-Sensitive Photographic Plates," issued November 6, 1919.

After the signing of the armistice the work was taken over, and is now being continued by the Color Laboratory of the Bureau of Chemistry. Altogether a large number of dyes of several chemical groups have been produced. The sensitizing action of all of them has been thoroly investigated by the Spectroscopic Section of the Bureau of Standards. These tests have served to guide the chemical investigators in the synthesis of known dyes and also of new ones. Dicyanin and some other infra-red sensitizers have been produced. A new dye known as kryptocyanin sensitizes in the orange and in a narrow region from wave-length 7200 to 7700A. This latter property will prove especially useful if the dye can be used in combination with pinacyanol. It seems very probable that there exist sensitizers for the infra-red more potent than any that are yet known. The best sensitizers in other regions have a comparatively narrow region of action. If this were true for the infra-red dyes it would mean that they have not yet been discovered, for the dyes that are now being used for this region are the *red* sensitizers which have been found to give the greatest extension into the infra-red. Therefore, a thorogoing search for new agents is of much importance and would seem to have excellent chances for success.

In England the Ilford Company, with the coöperation of Sir William Jackson Pope, K.B.E., F.R.S., was very successful in duplicating the German photographic dyes and in producing new ones. During the war they produced Sensitol Green, which is identical with pinaverdol; Sensitol Red, which is pinacyanol iodide, and Sensitol Violet, a new dye having somewhat the same properties as pinacyanol. These three dyes may now be purchased from Ilford Limited. The subject of the photographic dyes has been treated in a broad way by Professor Pope, and altogether some sixty varieties have been prepared in the chemical laboratory at Cambridge. The relationship between chemical constitution and sensitizing action has been studied and a few definite regularities have appeared. The work is now being extended in the direction of preparing new sensitizers for the infra-red.

Thus the war has made England and America independent of Germany in the matter of photographic dyes. It has also stimulated research as to their constitution and properties, which is already bearing fruit in improved sensitizers for certain regions, and which is highly promising for future progress. In a few years wave-lengths of 10,000 angstroms will probably be recorded as easily as those of 7,000 are today, and it may become practicable to extend photography to 20,000 angstroms.

As in the case of sensitizing dyes, certain dyes used to produce ray filters or light screens were formerly obtained from Germany and after the outbreak of the war were no longer available. Successful efforts were made by chemists of the allied nations to produce dyes that would give the required light absorption for various uses. Mention may be made of "Eastman Yellow," a dye evolved by chemists of the Eastman Kodak Company to replace Filter K, a German dye which had been used in making the well known series of Wratten K filters. The new dye gives filters which are said to be superior in optical properties and in stability. They are being placed on the market to supplant the "K" filters in a corresponding series with the designation "EK."

In many military situations it was necessary to have the finished print in the shortest possible time after the exposed plate was received at the dark room. It was even considered important to cut down the time of development to the lowest limit. To this end quick acting developers were employed. It was, of course, also desirable to have a developer which would give the greatest possible density to underexposed plates. Certain experts believed it possible to combine the two features in a single developer. The attempt was made to accomplish this by extremely concentrated developers often containing a large amount of caustic.

There is no subject upon which there is greater lack of agreement than that of developers. Certain developing agents or methods are used by one man to give density, by another to give contrast, by another to give "detail," while others deny their virtues for these results, or may even use the same procedure for opposite effects. There is accordingly no agreement as to the value of these concentrated developers. Some of them are difficult to prepare, and are apt to give trouble with chemical and dichroic fog. The general weight of opinion, however, seems to indicate that they possess a slight but real advantage for very weak exposures; in other words, that they tend to raise the lower part of the characteristic energy-density curve above the values given by other developers, and that they may thus serve to bolster up to usefulness a negative which would otherwise be hopelessly underexposed. At the Eastman Research Laboratories and probably elsewhere these concentrated developers involving both old and new developing agents are being made the subject of extensive study, which should lead to a determination of their value for various kinds of scientific work.

War-time experience in photography from airplanes should be an aid in numerous problems in civil life. It will surely prove so in cartography and probably in many unforeseen applications in technical and scientific work. The possibility of being assured of a view of an eclipse of the Sun by being prepared to soar above intervening clouds has already attracted attention. The idea is not necessarily chimerical. In some localities the chance of securing valuable observations from an airplane would be fully as great as from a station on the ground. Nor are photographic observations out of the question. A de Haviland plane with a Liberty motor, at 10,000 feet altitude, rides more smoothly than a train, and should permit direct photographs on a small scale, especially if the plane were equipped with a gyroscopic stabilizer. Snapshots of the flash spectrum could probably be made with an apparatus such as that used by Professor Frost at Green River on June 8, 1918. A modern plane would readily surmount any ordinary fog or cumulus clouds, tho cirrus is usually too high. Aside from cirrus clouds the observer would have a wonderfully clear, dark sky. By flying in the direction in which the shadow moves the duration of totality could be increased by five or ten per cent.

Some other scientific problems involving observations from high altitudes might be open to photographic investigations from airplanes. This would be the case if the essential apparatus were light and portable and did not require a stable foundation. To reach an altitude of 15,000 to 20,000 feet, it would be easier to ascend in a suitable airplane than to go on mule back up a mountain trail, and to reach much higher altitudes it would be the only way. The polarization of light scattered by the upper air could readily be recorded by means of the polarimeter recently developed by Anderson and Babcock[3]. The ultra-violet light from the Sun and its absorption in the Earth's atmosphere might well be studied from an airplane by taking up a small spectrograph. A very interesting possibility is that of detecting the solar corona. The sky light is the only thing that prevents observation of the corona, and the sky grows rapidly darker with increasing altitude. From 25,000 feet the sky light would be considerably decreased, especially in the longer wave-lengths, and if the corona possesses any strong radiations in the region around wave-length 7000, suitable methods might make it observable. Unfortunately not much is known about the coronal spectrum in this region. The use of shorter wave-lengths would not seem very promising, in view of the skillful attempts already made by Hale from mountain peaks, but it might possibly be worth trying from higher altitudes.

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[3] *Ap. Jour.*, **50**, 228, October, 1919.

If these observations or others of the same general character should be undertaken, certain war investigations would furnish useful information. Ingenious methods of recording very accurately the vibrations encountered in airplanes were developed and applied to various types of machines. The problem of mounting cameras and other instruments to be as free as possible from the effects of vibration received considerable attention. Data on the brightness of the sky from various altitudes were gathered by Luckiesh.[4] The files of the War Department probably contain other material of value in this connection.

The reader should note that in the foregoing paragraphs no attempt has been made to describe in true proportion the photographic achievements of the war. The only aim has been to give an account of certain features which seem to be of potential value to scientific research.

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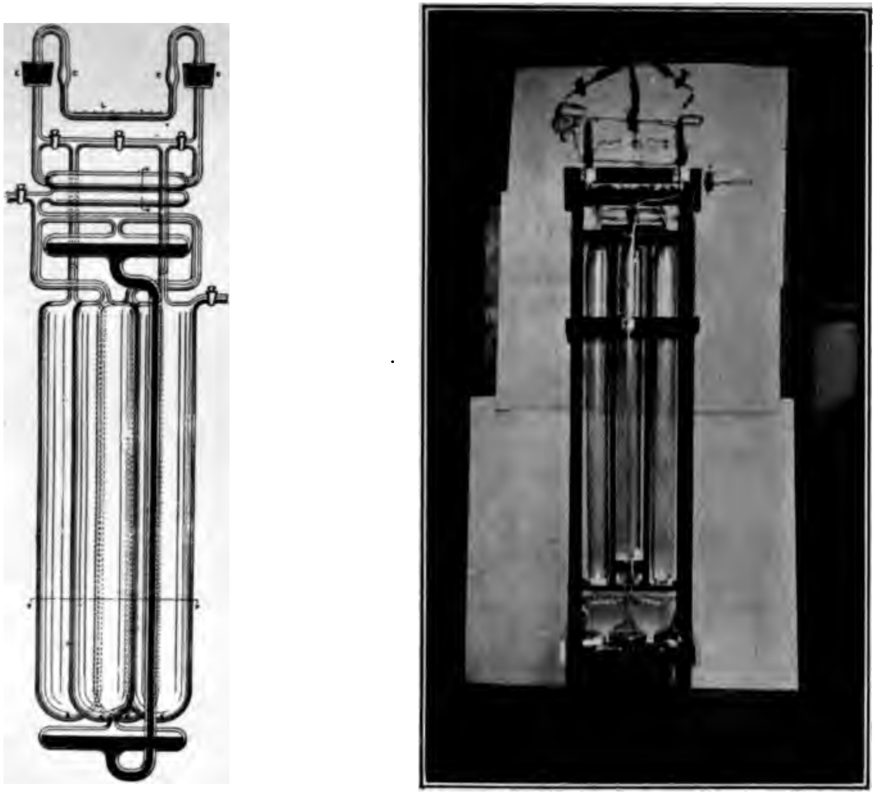
[4] *Aerial Photometry. Ap. Jour.*, **49**, 23, March, 1919.



A

B

PLATE II. A DIFFERENTIAL GRAVIMETER

A DIFFERENTIAL GRAVIMETER AND ITS APPLICATIONS[1]

By Luis Rodés, S. J.

Observatorio del Ebro, Spain

The fact that mutual attraction of masses, which in the case of the Earth we call gravity, is the force which rules the material universe, is so generally known that it does not need to be emphasized here. But altho the law of attraction is the best established and the most universal one, its nature is the most mysterious and the most hidden to our research. We do not even know if attraction acts thru the medium separating the bodies, as the law of the inverse square seems to point out; or if it has an immediate effect in masses without any action thru the medium; if it is propagated thru the medium we have no knowledge whatsoever about the speed of this propagation. F. Tisserand in his wonderful "Traité de Mécanique Céleste," devotes the whole of Chapter XXVIII of Volume IV to the subject, "Vitesse de propagation de l'attraction"; but his first words are the frank statement "on ne sait rien à ce sujet"; then, on the supposition of Laplace that attraction is due to the impulsion of a fluid, he arrives at the conclusion that such an impulsion should be propagated at least 6×10^6 times faster than light; while on the other hand, according to Einstein's theory, the velocity of light cannot be surpassed by any other velocity in the physical universe. Furthermore, physics has means for isolating sound, heat, magnetism, electricity, light; we have, so to speak, control of all these forces, but we are, or at least we are supposed to be, absolutely powerless to modify the effect of gravitation; let us say, we cannot change the weight of the mass.

The mechanical revolution which would be caused by the discovery of means for modifying the field of gravity is beyond the power of our imagination to picture. Yet, is it an intrinsic impossibility? In such a case all our attempts would be useless; we cannot change the nature of things. But if the attraction of two masses acts thru the medium separating the bodies, and, if in any way (excepting, of course, the change in distance) the effect of this cause can be modified, then an instrument to detect immediately any little difference in the force of attraction, cannot but have great importance in the study of the universal law.

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[1] An elaboration of the paper read at the 22nd meeting of the American Astronomical Society, held at Harvard Observatory, September, 1918.

The *pendulum* measures, indeed, with great accuracy the force of gravity, but due to its inertia *cannot detect a sudden change in this force*; it could be compared to a thermometer which could indicate only when or where *it is* cooler or hotter, but not when or where *it becomes* cooler or hotter. The instrument devised by the writer, the description of which will be the object of the present article, has above all the great advantage of responding instantaneously to any change of the gravitational field.

The principle consists in the use of a weight, mg, as a means of producing a certain pressure in a volume of gas. The variation of gravity will cause a corresponding change in the pressure, and consequently in the volume of gas, such, that the increment of volume, ΔV, will be proportional to the increment of g.

The simplest application of this principle would be to use a balloon full of gas, with a tube of constant cross-section (Fig. 1) containing a little mercury; the gas will be drawn off until its pressure is approximately equal to that of the column of mercury, the vacuum remaining in the upper part of the tube. The height and the mass of the column of mercury being constant, the pressure and therefore the volume of gas, will be a function of the gravity g. The formula giving this relation is $\Delta v_0 = v_0 \left\{ a\Delta t - \frac{\Delta g_0}{g_0} \right\}$, where v_0 is the volume at the given temperature t, for a given value of g_0, and a is the coefficient of expansion for gases. With such an instrument, in order to secure $1 \cdot 10^{-5}$ in the variation of g, the temperature should be measured, or at least kept constant within one three-hundred sixty-seventh of a degree Centigrade; this is a difficulty but not the one which makes this arrangement unsuccessful in practice. The true and only reason why I had to give up this model after various trials, is the friction of the column of mercury which prevents it from being moved along the tube by a force equivalent to $1 \cdot 10^{-5}$ of its weight, as would be necessary in order to get results of any scientific value.

An apparatus designed by Mascart and modified by Issel under the name of *gasvolumeter* has some fundamental resemblance to the one explained above, but Issel's instrument offers still greater disadvantages, as the height of the column of mercury does not remain constant, and the friction, far from being diminished, is still more increased. (See Svante Arrhenius, *Lehrbuch der Kosmischen Physik*, Leipzig, 1903, p. 246.) In this book the failure of the apparatus is attributed to the effect of temperature; but on bringing the instrument from the description to the laboratory it is easily seen that the real limit of its accuracy is set not by the temperature, which nowadays can be measured within a millionth of a degree, but to the friction of mercury in the capillary tube, as stated above.

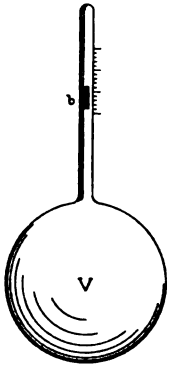

FIG. 1.

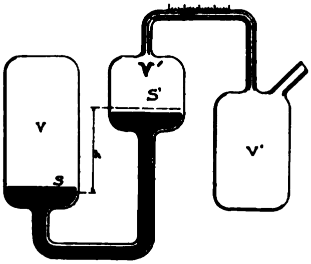

FIG. 2.

Five years having elapsed since the presentation of my first model to the Academy of Science in Barcelona, Spain, I devised another arrangement which, while retaining the fundamental principle, makes of it a completely new instrument in which friction is practically avoided. Its two essential features are as follows: first, to have a column of mercury with broad terminals, so as to make ΔV, the increment of volume, the greatest possible for any given change of its height due to the change of g; secondly, to measure this increment of volume by dividing it into two sections separated by a capillary tube in the interior of which there is a drop of alcohol as indicated in Fig. 2.

The pressure at V is equal to the pressure at V^1 plus the weight of the column of mercury h; as soon as the mercury changes its weight, due to the change of gravity, equilibrium will no longer subsist, and the pressure at V will be able to raise the column of mercury until this increment of height Δh, together with the corresponding increment of pressure at V^1, due to the diminution of this volume, will re-establish the equilibrium. The formula giving the increment of h, on the supposition of a constant and a uniform temperature, is $\Delta h = \frac{\Delta g}{g} \cdot \frac{h}{1 + \frac{(2a+h)S}{V}}$, where S is the chamber's cross-section, a, the pressure at V^1, and V supposed equal to V^1.

If we can measure experimentally Δh, or the increment in the column of mercury, we can deduce the increment in the force of gravity. If the terminals of the column of mercury have a great surface, let us say 200 sq. cm. or 20,000 sq. mm, which corresponds to a circle about six and a half inches in diameter, then an increment Δh of only one ten-thousandth of a millimeter will cause an increment of volume equal to Δh multiplied by S, or $10^{-4} \times 2 \cdot 10^4$, two cubic millimeters; but Δh is evidently equal to $\frac{\Delta V}{S}$, and hence it will be enough to measure ΔV experimentally. This increment of volume, given by the formula $\Delta V = \Delta h S = \frac{\Delta g}{g} \cdot \frac{h}{\frac{1}{S} + \frac{2a+h}{V}}$ will take place on both volumes with different signs, but on the one limited by S^1 will produce a corresponding change in the pressure and push

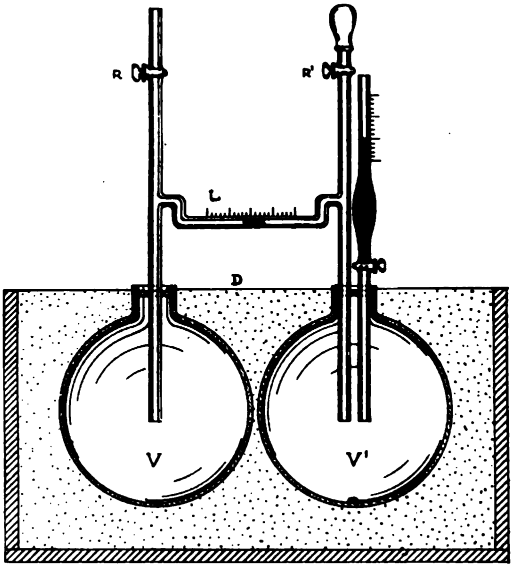

FIG. 3.

the drop of ether or alcohol towards the right until equilibrium is re-established.

In order to have reliable results, it is necessary to establish: *First,* that the index of ether or alcohol will be moved by so small a difference in pressure; *secondly,* that we can eliminate the effect of temperature. For testing the first I arranged two balloons about one liter each in volume, as indicated in Fig. 3. It was enough to reduce in some millionths the volume of gas in V^1 by dropping a few millimeters of mercury into it, in order to have an immediate displacement of the index towards the left. By pressing the small rubber bulb the same effect was obtained, and as soon as the pressure disappeared the index went back exactly to the same position.

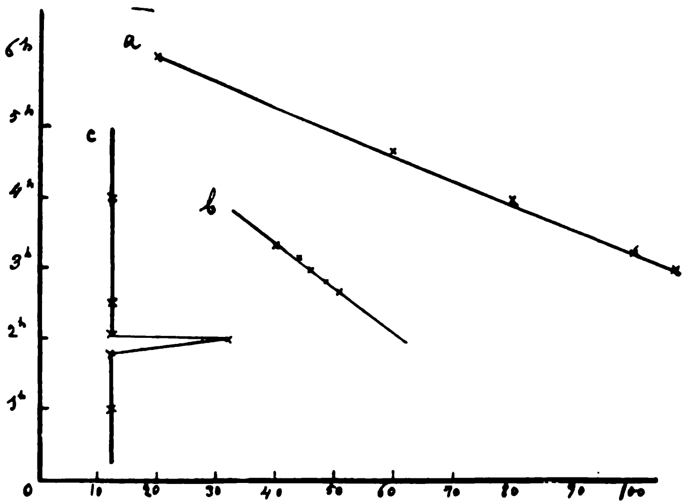

FIG. 4.

It is also required that the inner side of the capillary tube be free from dust particles and from any other imperfection changing the mobility of the index in its full run from one end to the other; it is not difficult to obtain this when using chemically clean tubes and liquids which adhere to the walls; anyway it can be tested with complete accuracy by letting the index fall along the tube a little inclined and recording its position at different intervals of time; if the friction is constant the movement will become and remain uniform. How faithfully this condition was fulfilled appears in the diagrams Fig. 4, in which the position of the index has been plotted against the time; *a* was obtained with a drop of acetic acid, inclining the tube so as to have a force of about one hundredth of a milligram acting upon the index; the ordinates are measured in hours and the abscissae in millimeters; *b* was obtained with a drop of ether, the component of gravity acting upon it being one three-hundredth of a milligram; here the divisions of the ordinate represent minutes; *c* shows stationary oil index obtained with an arrangement like the one in Fig. 3, altho the two balloons were here very much smaller in order to secure a uniform temperature; the sudden displacement of the index was caused by applying the hand to one of the bulbs; about fifteen minutes later, the index was found again in the original position.

Coming now to the temperature, it can affect the instrument in two ways: by not being uniform, and by not remaining constant. The error arising from the first source is given by formula

$$\Delta V = S\Delta h = \frac{VP\left\{\frac{T^1}{T} - 1\right\}}{P\frac{T^1}{T} + p + \frac{V}{S}},$$

where T is to be measured in absolute Centigrade degrees, P and p are the pressure at V and V^1, and these two volumes are supposed to be equal. This error can be practically eliminated by arranging the two volumes V and V^1 of Fig. 2, in a series of bulbs very close together (see Plate II, A) and, if necessary, placing all the bulbs inside another one enveloping them, which would also eliminate better the effect arising from any change of pressure from the outside. Practically no great danger is to be feared from this source.

The effect of any change in temperature, supposing it to be uniform, is given by the formula

$$\Delta V = \frac{Vh\left\{\frac{T^1}{T} - 1\right\}}{\frac{T^1}{T}(P + p) + \frac{V}{S}},$$

where P, p and h are to be measured in millimeters of mercury.

Comparing (*a*) the increment of volume ΔV_1, due to Δg equal only to 10^{-6}; (*b*) the increment ΔV_2 due to a difference of temperature of one-thousandth between the two volumes separated by the column of mercury; and (*c*) the increment of volume due to a change of temperature of one-thousandth on both volumes, and taking as constants for the instrument

$V^1 = V = 10^6$ cu. mm (cubic millimeters)
$S = 10^4$ sq. mm
$h = 500$ mm
$P = 750$ mm of Hg.
$p = 250$ mm of Hg.
$T = 300°$ abs. C.

we shall have:

$\Delta V_1 = 0.45$ cu. mm
$\Delta V_2 = 2.27$ cu. mm
$\Delta V_3 = 1.36$ cu. mm

ΔV_2, which has the greatest value, can be practically eliminated; ΔV_3, or the increment of volume arising from a variation of temperature of one-thousandth of a degree Centigrade, is still three times greater than ΔV_1 corresponding to a variation of one-millionth in the value of g and about equal to the one caused by variation of g equal to three-millionths, corresponding to an increment of the distance from the center of the Earth, R, of about nine meters, as can be seen from the formula $\frac{g_0}{g} = \frac{(R+d)^2}{R^2} = 1 + \frac{2d}{R} + \frac{d^2}{R^9}$.

Hence, by measuring the temperature in thousandths of a degree Centigrade, heights could be measured within ten meters independently of the atmospheric pressure, and with a constant sensitiveness at any height. A spiral tube in a horizontal plane would allow a wider range for the index, or it could be used by proceeding in steps. In taking readings the instrument should be suspended.

The industrial applications of such a differential gravimeter for use as an *altimeter* will be limited by the industrial facilities in measuring temperatures. But that is not the case with very important laboratory work. Even without the proper means for it, I have kept the temperature constant within one-thousandth of a degree Centigrade during many hours, and no serious difficulties would be presented in observatories and laboratories provided with special rooms for constant temperature. Besides that, the temperature varies so slowly with the proper isolation of the instrument, that the movement of the index can be practically determined qualitatively and quantitatively within a rather great range of time during which the action of g could be tested, and its effect easily distinguished from the curve due to the temperature.

It seems that in dealing with laboratory work, the only limit to the sensitiveness of the instrument comes from the friction of the index. When using ether, which shows the greatest mobility in a capillary tube, I found that, for a tube of one square millimeter section and a column of ether one millimeter long, the friction is smaller than one two-hundredths of a milligram. By projecting the shadow of the index upon a graduated scale the sensitiveness of the instrument could be carried well beyond $1 \cdot 10^{-7}$.

Let me now enumerate some of the main features of the complete instrument as shown in Plate II, A. The two bulbs with the terminals of the column of mercury are very much flattened so as to have a great surface, minimizing at the same time the effect that any difference of temperature between these two bulbs, which cannot be kept together, could have on the final results. The capillary tube is removable and attached to the instrument with a completely air-tight junction as shown in Fig. 5. The stop-cocks are of the form shown in Fig. 6, which prevent any air from escaping from the bulbs; when the three stop-cocks below the capillary tube are open, communication is established between the two sections of the volume V^1 (Fig. 2) and the index can be brought to any convenient position; when the central stop-cock alone is closed, differences of pressure are transmitted to the index; the closing of the other two cuts off the indicating tube from the oscillations of the mercury when moving the instrument; the other stop-cock, below at the left, is for pumping out the air until a convenient height of the column of mercury is obtained, while the last one at the right is for the introduction of mercury.

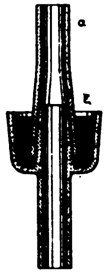

FIG. 5.

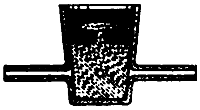

FIG. 6.

The three small cylindrical bulbs disposed horizontally at the upper part of the instrument and which can be seen in a transverse section on the left side of the plate, are intended to contain ether, thus preventing the evaporation of the index; one of these bulbs communicates with the volume V and the other two with both regions of the volume V^1. They have to be kept close together in order to secure a uniform temperature; when oil is employed, for work not requiring such a high degree of sensibility, these three bulbs can be eliminated.

A complete model with all these necessary details has not yet been finished; but a trial instrument was made in the Ryerson Laboratory of the University of Chicago, where Prof. A. A. Michelson, its director, gave us every facility for carrying on the preliminary experiments, and on his recommendation Dr. Ishida, with an interest and a constancy which I deeply appreciate, constructed the model which can be seen in Plate II, B. The lack of proper junctions and stop-cocks, and the excessive height of the column of mercury (determined by the distance between the lower and the upper bulbs) which, together with the vapors of ether, gave a pressure far in excess of that due to the outside atmosphere, were responsible for a continuous leaking of the instrument, which prevented quantitative measurements; but even so, the great sensitivity of the instrument was made manifest by an indirect process. When starting a movement of the instrument upwards or downwards, or when giving a new acceleration in the direction of the vertical, the column of mercury must, on account of its greater inertia, increase or decrease the pressure upon the gas, and consequently produce a sudden increment of volume. Accordingly we brought the apparatus to an elevator; as soon as we started upwards the push was so great that the index was suddenly carried out of the capillary tube; in coming down the phenomenon was repeated in the opposite direction. We then placed the instrument on a small platform which could be raised very slowly by means of a worm screw; the acceleration was so small that nobody could detect directly the rising of the instrument; nevertheless every time that I pushed the screw in one or another direction the index was displaced from twenty to thirty millimeters in the capillary tube.[2]

At present that is all that can be positively asserted about this differential gravimeter. As to its possible applications for the future I may point out the following:

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[2] From this it is clear how the instrument can be employed as an *accelerimeter* by establishing a narrow communication between the two sections of volume V^1 of Fig. 2, which would destroy the permanent effect due to the change of g and at the same time would let sudden changes of g be transmitted to the index. In using the instrument as an *altimeter* the effect of sudden changes, due to a change of acceleration, could be eliminated by conical valves properly adapted between the two sections of the volume.

(1) For the geophysical observatories, in order to study variations of *g* in possible connection with earthquakes; or if the instrument is constructed as an accelerimeter to use it as an exceedingly sensitive seismograph in recording the vertical component.

(2) For possible laboratory work in studying the nature of *g*. If by means of a strong magnetic field gravitation could be changed in one ten-millionth, the instrument would detect this variation.

(3) To study the value of *g* on different places of the Earth with possible connection with some small changes in latitude.

(4) For comparing the mass of a ton with the mass of the Earth, or, in other words, for weighing the Earth, possibly repeating with less difficulty the experiments carried on by Cavendish in 1798.

(5) For detecting the change in the field of gravitation due to the position of the Moon on the horizon, which amounts to a little more than one ten-millionth.

(6) For measuring heights independently of the atmospheric pressure, if constancy of temperature could be secured within one-hundredth of a degree.

These are the main applications, some of which I hope to be able to test in the Observatorio del Ebro, Tortosa, Spain; meanwhile I would consider it a great reward for my work if I could contribute in any way to break down the barrier which has prevented us from entering into the dominion of the force controlling the Universe.

September, 1919.

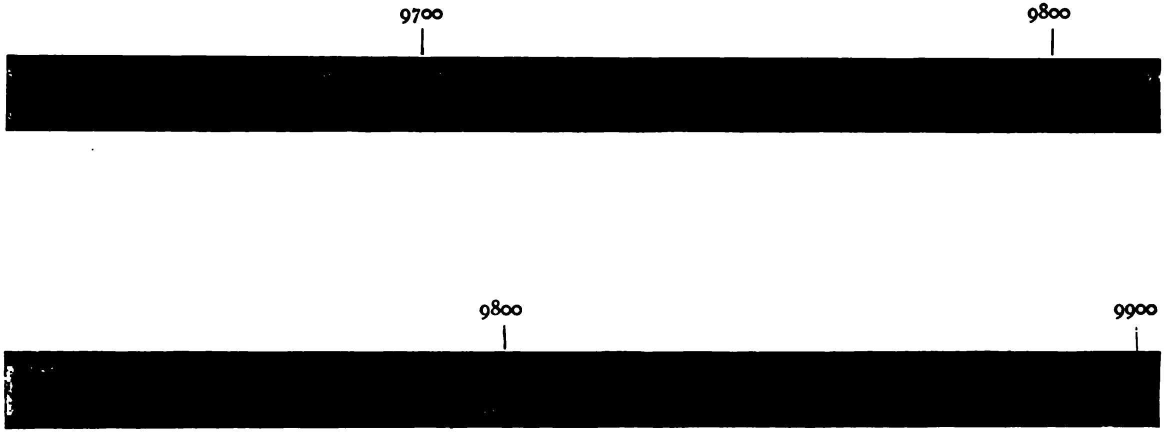

PLATE III. THE INFRA-RED SOLAR SPECTRUM. 9640 A TO 9900 A

THE SOLAR SPECTRUM IN THE REGION 9000 A TO 9900 A

BY KEIVIN BURNS

Beginning with the shortest wave-length which penetrates our atmosphere, about 2930 A, and extending to 9000 A, the solar spectrum has been well observed. The greater part of the lines in the spectrum have been identified as belonging to the various elements, or as due to the absorption of the Earth's atmosphere. Beyond 9000 A the solar spectrum has been photographed as far as 9600 A by Meggers[1] and as far as 9867 A by Abney[2], but no lines were identified by them. In this region beyond 9000 A the wave-lengths of the lines in the spectrum of iron and associated elements have been determined in the laboratory. Since these are the elements whose lines are most numerous in the better known part of the solar spectrum, it seemed that the lines due to these elements would be found also in the region of wave-lengths longer than 9000 A, and that the wave-lengths of all the solar lines in this region could be determined by means of them. This investigation was undertaken to identify as many solar lines as possible in this region; to measure the wave-lengths of all the lines by means of laboratory standards; and to separate the solar lines from those of terrestrial origin.

The 36-inch telescope and the spectrograph described by Campbell and Albrecht in *Lick Observatory Bulletin*, **6**, 11, 1910, were used for photographing the region beyond 9000 A. The photographic plates were Seed 23, sensitized by means of dicyanin furnished by the U. S. Bureau of Chemistry. The dye from the Bureau of Chemistry proved to be somewhat superior to the samples of foreign dye in my possession. In using dicyanin it is of considerable importance to have fresh dye, and the possibility of obtaining this dye in this country will be greatly appreciated by American spectroscopists.

The grating of the spectrograph is brilliant in the second order on one side, and this order was used for this investigation. The scale is about 10.5 A per millimeter, and the resolving power about 90,000. The aperture ratio of the camera is F8. The speed of this camera is so great that the exposure time in the red of the solar spectrum (6600 A) is only a small fraction of a second; and yet the detail which may be observed in the spectrum is as great as in the case of any spectrograph which has ever been used for wave-lengths greater than 7600 A.

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[1] W. F. Meggers, *Ap. Jour.*, **47**, 1, 1918.

[2] W. de W. Abney, *Phil. Trans.*, **171**, 653, 1880.

While the discovery of dicyanin has made it possible to observe a great extent of spectrum which could not otherwise be photographed, it may be of interest to consider the difficulties which are incident to work in this region. It should be remembered that the solar intensity drops rapidly with increasing wave-length, after passing the maximum in the green. And while dicyanin is a very valuable dye for use in the near infra-red, 7700A-9900A) its maximum sensitizing power is in the red, and it greatly decreases with increasing wave-length. Around 9800 A the necessary exposure time is 40 minutes, with the apparatus mentioned in this article. Using the same slit width, and screens of equal transparency to the region in question, the exposure would be only 2 minutes at 9100A; 35 seconds at 8400A; only 0.2 seconds at 6900 A and at Hα. It is seen from this that the combination of changing spectral energy and variation in sensitizing power of the dye makes the photographic intensity over ten thousand times as great in the red as it is in the region in which we are especially interested at present, namely, beyond 9000 A. Certain difficulties arising from this source will be mentioned later.

In observing by means of a grating it is usually necessary to take some precaution to eliminate the overlapping spectra of other orders. In the region which is commonly photographed in astronomical work, the overlapping orders can generally be avoided by the choice of a plate insensitive to the orders of greater wave-length, or by a screen which is nearly opaque to the orders of smaller wave-length. When we come to observe the infra-red in the second order the problem is not so simple. The third order red overlaps the second order infra-red which we wish to photograph, and we have seen above that the photographic action is over ten thousand times greater in the red than in the region we wish to study. The third order of the grating used in this work is about one-fourth as brilliant as the second for equal wave-lengths; consequently our screen must reduce the red by a factor of twenty or thirty thousand in order that it may not interfere with the second order spectrum. Usually a screen which reduces the higher orders by a factor of one hundred is entirely satisfactory, since the discrepancy in sensitivity is seldom so very great in the region of spectrum which is ordinarily photographed. And a screen which transmits only one-hundredth of one per cent of the energy at a given wave-length is rated as opaque for that wave-length. We must have a different order of opacity in infra-red work, and no screen which I have examined transmits less than one ten-thousandth of every visible wave-length, if the screen is thin enough to transmit forty per cent of the energy at 9800 A. In practice, the overlapping green and blue light was absorbed by a screen of selenium red glass, and the red was eliminated by a cobalt blue glass and two Wratten B green filters. This combination of four screens reduced the intensity of the infra-red to about five per cent of that falling upon the first screen.

If the spectrum were being photographed in the first order it would be somewhat less difficult to remove the overlapping orders, as in that case the longest overlapping wave-length is only half that of the region under observation. But in either case there would be two other difficulties to be overcome in observing the region 9800 A, namely, scattered light and false spectra. These are just as bad in the first order as in the second. Light is scattered by imperfections in the glass of the lenses and by dust particles or miniature scratches on the surfaces of the lenses and grating. If this scattering amounts to one part in a thousand, it is evident that the stray light must be greatly reduced before the region 9800 A can be observed. Without a screen, the scattered light of wave-length 7600 A would blacken the plate as readily as the total light at 9900 A. However, when the third order has been eliminated as described above, the scattered light is not very noticeable in an hour's exposure.

The false spectra, or Lyman ghosts, are the source of the difficulty which is hardest to overcome. When light of a definite wave-length, such as sodium D light, falls upon a grating it is reflected or diffracted in certain definite directions which may be computed by a simple formula as a function of the wave-length. Substituting zero in this formula shows the position of the direct reflection; the number one gives the position of the first order; two gives the position of the second order; etc. A perfect grating would throw all of the light into the direct reflection and the various orders represented by whole numbers. In practice, however, a small part of the light is thrown into directions which correspond to fractions. For this reason we have light of wave-length about

7000 A and even 8000 A overlapping the region we wish to observe at 9800 A. And this will be true no matter what order we use. Now in the nature of the case, the nearer two wave-lengths are to each other, the harder it is to isolate them by means of screens. Since the sensitivity is hundreds of times greater at 8000 A than at 9800 A, it follows that a comparatively weak ghost (false spectrum) of the former wave-length may be very troublesome. The spectrum which could be photographed in the present investigation was limited by the presence of these false spectra rather than by the overlapping higher orders, scattered light, or waning sensitivity of the plate. Beyond 9900 A the screens at my disposal reduced the light of the desired wave-length too much in proportion to the reduction made in the false spectra, thus making the exposure times too great to be feasible. Undoubtedly in the near future a careful investigation of existing screens and the production of new ones will do more than anything else to advance the spectroscopy of the infra-red.

Plates were taken thruout the region 8900 A-9900 A, overlapping the known region by one hundred angstroms. I am indebted to Dr. Meggers for a manuscript copy of his paper which gives the wave-lengths and identifications of solar lines in the region 6500 A-9000 A. In the region 8900 A-9300 A the plate constants can be determined from the known lines of wave-length less than 9000 A. The wave-lengths in the unknown region 9000 A-9300 A, particularly in that part which adjoins the known region, can be found with some accuracy. However, this method of measurement did not lead to the identification of any solar lines with metallic lines which had been measured in the laboratory.

The fourth order, 4500 A-4650 A, is in fairly good focus when the spectrograph is adjusted for the second order in the region 9000 A-9300 A. The second and fourth orders in these regions of the solar spectrum were photographed side by side on the same plate, and the wave-lengths of the infra-red lines were determined by means of the known lines of shorter wave-length. The resulting values of the infra-red wave-lengths are not very exact; still they are accurate enough to show whether or not there are any solar lines which correspond in wave-length with the lines of iron and other elements which have been measured in the laboratory. In the case of the iron spectrum there is a line near the position of each strong iron line, but the intensities do not agree with the laboratory results, and in order to consider these lines as due to iron it would be necessary to suppose the errors of measurement to be far greater than seems possible. In the case of the elements chromium, manganese, nickel, cobalt, vanadium and titanium, it is certain that their lines are too faint to be observed in this region without greater resolving power than 90,000.

In many cases these metallic lines may have been hidden by atmospheric (terrestrial) absorption lines, or blended with them. But in the majority of cases no line of intensity 00 on Rowland's scale is found in the neighborhood of the laboratory wave-length. These lines are no doubt present, but it will require greater resolution than 90,000 to show them, on account of their faintness. This is in keeping with what is known of the part of the solar spectrum which has already been observed. The absorption lines of the metals are very strong in the ultra-violet and violet, not so strong in the visible region, and weaker in the longer red and the infra-red. The strength of the telluric lines increases, on the other hand, with increasing wave-length, and the number of these lines also increases.

As the Sun is in fairly rapid rotation, the observed wave-lengths of the solar lines are shorter than normal at the east or approaching limb, and longer at the west or receding limb. The difference in wave-length for the two limbs amounts to 0.13 A. The telluric lines, on the contrary, have the same wave-length on all parts of the Sun and at all times, being due to our own atmosphere which has no motion with respect to the observer which can be detected by a displacement of spectral lines. This well-known effect of the Sun's rotation has been utilized by Dr. Meggers[3] to separate the lines of solar origin from those due to our atmosphere in the region 5800 A-9000 A.

In order to separate the two types of lines in the region 9000 A-9900 A, spectrograms of the east and west limbs of the Sun were obtained thruout the entire region. In the region 8960 A-9300 A two spectrograms of each limb were measured and the differences were taken. The mean error of a difference, east minus west, was found to be 0.04 A. If there had been any considerable number of solar lines present the differences would have clustered around two valves differing by 0.13 A. The differences fell pretty well on a probability curve whose center is at zero, as shown by lines of known terrestrial origin. Thruout the whole region plates of the east and west limbs were compared on the Hartmann spectrocomparator. Only three displacements were found, and these may be due to photographic effects. As a check on the accuracy of these comparisons a similar comparison was made of two plates in the region of 7600 A. The velocity shift was easily seen in the case of the stronger lines. It is likely that hazy lines and faint lines would not show the velocity shift with certainty. Beyond 9300 A the character of the observations deteriorates, so that the evidence in favor of the absence of solar lines is not so conclusive. It seems likely that in the region 9000 A-9250 A there are few, if any, lines of solar origin of intensity 0 or greater on Rowland's scale, and beyond 9250 A it is almost certain that all the strong lines are due to absorption in our own atmosphere. The region under discussion may always be of small interest, considered as the solar spectrum; but it is sure to be of interest in studying the absorption lines due to the gases of our own atmosphere. We cannot distinguish at present between the lines due to the various gases of the atmosphere. However, many lines have different intensities on different plates, and this suggests water vapor as their source. All the strong lines in the neighborhood of 9300 A show this variation.

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[3] Unpublished Ms.

The accompanying plate shows the spectrum beyond the region observed by Meggers.[4] The last few lines are of longer wavelengths than any observed by Abney[4]. The photograph has a very different appearance from that of Abney's diagram due to the presence of fainter lines on my plate, and the resolution of several groups which were seen as single lines by Abney.

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[4] *loc. cit.*

A STUDY OF THE PLEIADES CLUSTER

By Robert Trumpler

The comprehensive study of the *Pleiades* cluster now in progress may be divided into four distinct parts:

1. A series of accurate measures of the relative positions of the stars.
2. A determination of the proper-motions of these stars by means of all observations now available.
3. A determination of the magnitude and spectral type or color-index of the stars.
4. A statistical investigation of the constitution of this interesting cluster, based on the results of the first three parts.

The addition of a fifth part studying the radial velocities would be desirable. So far radial velocity measures have been made only for a few of the brightest *Pleiades* stars, and their spectral type (B5-B8) is not favorable for obtaining accurate results. With the aid of one of the new large reflectors it should be possible to obtain radial velocity determinations for some of the fainter group members (6-9th photogr. magn.), the spectra (A0-F0) of which are better suited for such measures.

1. Measures

The program for the new measures of the relative positions of the stars was chosen so as to serve best the purpose of determining proper-motions suitable for statistical investigations. The apparent diameter of the *Pleiades* cluster was determined from star counts on the B. D. charts. It was found that the cluster extends as far as 3° from the center, and this result has been confirmed by the study of the proper-motions.[1] Most of the earlier observers had confined their measures to stars within less than 1° from the center. As the work of measuring the fainter stars in such a large field would have been too great, the star list was divided into two parts: The first part consists of the 243 stars of the *Astronomische Gesellschaft Catalog* within a circle of 3° around the center of the cluster; it is complete for all stars (198) equal to the magnitude 9.0

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[1] *Publ. of the Amer. Astr. Soc.*, **3**, 333.

of the B.D. or brighter. The second part contains 964 stars within a square of 2° side having *Alcyone* at the center, and is complete for all stars (914) brighter than the photographic magnitude 14 5 (Hertzsprung's scale[2]). Since the two lists have some stars in common, and including some stars measured for technical reasons outside the limits of both lists, the total number of stars measured is 1180.

For the measures made at the Allegheny Observatory by the photographic method, plates taken with three instruments of different focal lengths were used:

The 3-inch Doublet Camera of the Allegheny Observatory (f=1630mm): 7 plates.

The Astrographic Refractor of the Zurich Observatory (f=3435mm): 1 plate, secured and kindly lent by Professor Wolfer.

The 30-inch Photographic Refractor (Thaw Telescope) of the Allegheny Observatory (f=14130mm): 15 plates.

2. PROPER-MOTIONS

The determination of the proper-motions is based on the measures just mentioned together with all previous accurate observations. The idea is to form a catalog of the mean positions and proper-motions of the stars giving the best results at present attainable, which should represent and replace the numerous measures scattered thruout astronomical literature. Any work on proper-motions will, of course, be superseded in time; such a collective catalog should, however, greatly facilitate any future work, as it can easily be combined with additional observations.

The observations used for the determination of the proper-motions are taken from 129 catalogs of meridian observations made between 1745 and 1915 and from 40 series of measures made with the heliometer, micrometer, or by photography. The number of catalog positions is about 12,000 in each coördinate, and these represent the results of about 25,000 individual observations in each coördinate.

To obtain the best results a new uniform reduction of the previous measures is necessary, as well as a determination of their accuracy, which will permit us to attribute to each measure the proper weight. The positions and proper-motions of the new catalog are based on the system of Boss' *Preliminary General Catalogue*. The most important items of the new reductions are to correct the meridian observations for errors depending on the magnitude of the stars and to determine the correct scale value and position-angle orientation for the measures made with the heliometer or by photography. The severe test to which all measures were subjected gives a great amount of information about the systematic errors and the accuracy of the different methods for measuring the relative positions of stars.

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[2] *A. N.* **199**, 251.

From the corrected observations the mean position for the epoch 1900.0 and the proper-motion are derived by least-squares solutions. For the brighter stars the observations are very numerous; for the fainter stars the proper-motions are principally based on the following series of observations:

The micrometric measures of 63 faint stars made by A. Hall with the 26-inch refractor of the Naval Observatory (1886-1888), repeated by E. E. Barnard with the 40-inch Yerkes telescope (1903-1906 and 1917-1919). The photographic measures of 263 stars by F. J. M. Stratton (1892 and 1906).

The Astrographic Catalogue zone of the Paris Observatory (1892-1899).

The Astrographic Catalogue zone of the Oxford Observatory (1894-1909).

Besides these published observations the following early photographs of the *Pleiades* were measured and reduced by the writer:

Three plates taken with the Astrographic telescope of the Oxford Observatory (1891-1893) kindly lent by Professor Turner (of which one is an exposure of 2^h) and one plate taken with the 36-inch Lick telescope (1890) covering a part of the central field.

For the brighter stars (3-8 magn.) of the central region the probable error of the proper motion is approximately $\pm 0''.1$ per century, which is about 2 per cent of the proper-motion of the group. The catalog therefore will be able to predict the relative positions of these stars for the next 50-60 years within a probable error of less than $\pm 0''.1$. With decreasing brightness of the stars the accuracy of the proper-motions of course diminishes, but even for the fainter stars (12-14.5 magn.) the average probable error of the proper-motion does not exceed $0''.5$ per century.

3. MAGNITUDE AND SPECTRAL TYPE

For a cluster like the *Pleiades* all group stars are, as far as their magnitudes are concerned, practically at the same distance from us, and the observed magnitudes give us direct information about their relative luminosity. To obtain the absolute magnitude (the brightness of a star as seen from the unit distance) we have only to add a constant, depending on the distance of the cluster, to the observed magnitudes.

The new *Henry Draper Catalogue* gives the spectral types, determined at the Harvard Observatory, for most stars of the first part of our program (the brighter stars within the field of 3° radius), and the photographic magnitudes of all stars outside the central field were determined with the aid of the 3-inch Doublet Camera and the 30-inch refractor of the Allegheny Observatory. For the central field Dr. Shapley of the Mount Wilson Observatory has taken over the task to determine the magnitudes and colors of the stars according to the method used in his "Studies Based on the Colors and Magnitudes in Stellar Clusters."

4. STATISTICAL INVESTIGATION

As the work on the proper-motions is not yet finished, it is for the moment only possible to indicate the lines which this investigation has to follow together with a few preliminary results.

Our star list still contains a number of stars which are projected on this part of the celestial sphere only from our point of view, but are situated either in front of or behind the cluster and have no physical connection with it; we shall call them the background stars. Our first step is to separate the group members from the background stars. For this purpose proper-motion and spectral type may serve as criteria, as the proper-motions of the brighter *Pleiades* stars are found to be very nearly parallel and equal, while the spectral type seems closely related to their luminosity.

Considering for the moment only those stars marked as group members, we may proceed to study their distribution among the different degrees of luminosity as well as their special distribution. Counting the number of stars for each magnitude interval we obtain what we may call the *luminosity law* of the cluster. The following Table 1 gives the preliminary results for this law separately for the central circle of 1° radius and for the whole cluster; for the fainter stars the photographic magnitudes are estimates based on Hertzsprung's scale.

TABLE 1

LUMINOSITY LAW OF THE PLEIADES

	Within 1° from Centre			Whole Cluster	
Photogr. magn.	Group stars	Backgr. stars	Per cent gr. st.	Group stars	Average spectr. t.
2.5- 3.5	1	0	100	1	B5
3.5- 4.5	5	0	100	5	B6
4.5- 5.5	2	0	100	2	B7
5.5- 6.5	7	0	100	8	B9
6.5- 7.5	10	3	77	18	A0
7.5- 8.5	16	1	94	24	A2
8.5- 9.5	13	5	72	30	F2
9.5-10.5	13	8	62		(F9)
10.5-11.5	23	30	43		
11.5-12.5	37	55	40		
12.5-13.5	29	103	22		
13.5-14.5	38	289	12		
>14.5	7	44	14		
Total.......	201	538	27		

Tho the figures may undergo some small changes when the definitive results are available, the table proves beyond doubt that the members of the *Pleiades* group are spread over a large range of luminosity, exceeding twelve magnitudes; i. e., the brightest member is over 50,000 times more luminous than the faintest group stars observed. The number of group stars for each magnitude interval increases very gradually as the stars become less luminous and may perhaps reach a maximum near the limit of our table. The progress of these numbers indicates that we should expect group members even fainter than our magnitude limit. The fourth column of our table tells what per cent of all stars of any magnitude interval are group members. While nearly all the brighter stars of the central region are members, only a small percentage of the fainter stars belongs to the group; this explains why the cluster is conspicuous only by the brighter stars. It may be interesting to note that this preliminary luminosity law of the central region of the *Pleiades* differs considerably from that of the fixed stars in the average as established by Kapteyn[3] and Schouten[4] in so far as the *Pleiades* stars seem to have a larger range of luminosities. The same result has been found for the cluster *h Persei* by means of star counts.[5]

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[3] *Gröningen Publ.*, Vol. 11.

[4] *The Statistical Laws of Stellar Astronomy. (Diss.)*

[5] R. Trumpler, *Comparison and Classification of Star-Clusters. Publ. of the Allegheny Observatory* (in press).

The last column of Table 1 gives evidence of the remarkable relation between the spectral type and luminosity of the *Pleiades* stars.

Counting the group members in successive concentric rings around the center of the *Pleiades* and dividing the numbers by the surface of the rings we obtain the star densities (star numbers per square degree) at different distances from the center, or the *density law*. Table 2 contains the preliminary results for this relation for the stars brighter than the magnitude 9.0 of the B.D.

TABLE 2

DENSITY LAW OF THE PLEIADES

Distance from Centre	Group Stars	Star Density
0 –0°.5	28	35.9
0.5–1.0	22	9.3
1.0–1.5	10	2.5
1.5–2.0	10	1.8
2.0–2.5	6	0.8
2.5–3.0	8	0.9
>3.0	(2)	

We have a very rapid decrease in the star density between 0°.5 and 1° from the center and that is the place where most observers have estimated the limit of the cluster. This concentrated part, however, is surrounded by a region which on account of the small density of the group stars is not conspicuous but which by its large surface yet contains a considerable part of the group members.

As to the proper-motions we are most interested in the internal motions, i. e., the movements of the individual stars with respect to the center of gravity of the whole cluster. The statement made above that the proper-motions of the *Pleiades* stars are very nearly parallel and equal is equivalent to saying that the internal motions are small as compared with the motion of the group, which is $5''.3$ per century. The small differences between the observed proper-motions of the group stars are due to two causes: to errors of observation and to internal motions. It is for this reason that the accuracy of the observations has to be determined very carefully, so that we may evaluate how much of the observed differences comes from the first source and what is the average amount of the internal motions. The internal motions need not be of the same size for all classes of stars; they may vary with their luminosity or their distance from the center of the cluster.

The fact that the observed radial velocities (Adams, Hartmann) of the six brightest stars differ considerably while their proper-motions are so nearly alike is rather puzzling. If the radial velocity observations are correct it can only be explained by the assumption of a very great distance of the *Pleiades* ($\pi < 0''.002$).

It will further be of interest to test, whether the internal motions have a tendency to give the group a rotational movement or to produce a contraction in the size of the group. The latter effect may be expected from the radial velocity observations which indicate that in the mean the group is receding from the solar system at a speed of 10 km a second. The amount of this contraction, or what is equivalent to it, the converging point of the proper-motions of the group stars will give some information about the distance of the *Pleiades*, as it is proportional to the parallax. If we assume the parallax of the *Pleiades* as 0''.01, two stars distant 1° should seem to approach each other by 0''.037 per century. Altho this is extremely small it should be possible to detect an effect of this size with the aid of the group stars situated at distances between 1° and 3° from the center.

In Table 3 the different methods giving information about the parallax of the *Pleiades* are put together. The result so far obtained show rather a large range.

TABLE 3

THE PARALLAX OF THE PLEIADES

1. Direct measure of relative parallax	$\pi = -0''.002 \pm ''.011$ (Yale)[6]
2. Converging point of proper-motions	
3. Average intern. motion in p. m. and rad. vel.	$\pi < 0''.002$
4. Group motion (supposing Pl. at rest)	$\pi = +0''.014$ (Hertzsprung)
(supp. it par. to plane of milky way)	$\pi = +0\ .018$ (Kapteyn)
	$+0\ .024$ (Plummer)
5. Orbital motion of binaries[7]	
6. Mean abs. magn. of B-type stars (3-7 magn.)	$\pi = +0\ .006$ (Hertzsprung)
Mean abs. magn. of st. 5.5-9.5 m. from sp. type	$\pi = +0\ .005$ (W. H. Pickering)
7. Luminosity law	$\pi = +0\ .036$ (Schouten)

While the first three methods are based on geometrical considerations only, the others require some more or less plausible assumptions.

Incidentally the proper-motions, magnitudes and colors optained for the background stars will be useful for statistical investigations on the stellar system in the average.

ROBERT TRUMPLER.

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[6] Derived from the results in *Yale Trans.* **2**, 215, by using the measures of the 3 group stars E8, E43, E62, and the one comparison star E36 with small p. m., the parallax of which was assumed according to van Rhijn's table (*Ap. Jour.*, **43**, **41**).

[7] There are three close double stars sharing the proper motion of the *Pleiades* group, which seem to show orbital motion: β536, β537, β1105.

J. H. JEANS: PROBLEMS OF COSMOGONY AND STELLAR DYNAMICS. CAMBRIDGE, 1919; A REVIEW

By Gustaf Strömberg

In an essay with the above title the well-known English mathematician, J. H. Jeans, has published an investigation of the stability of rotating gaseous masses and, from a purely theoretical study of this problem, has arrived at conclusions which are very important in the study of stellar dynamics and the evolution of the stars.

The main part of the book contains an extensive mathematical study of the evolution of configurations for a rotating and gravitating gaseous mass, dealing especially with the stability of the different configurations. It is an extension of the work by Laplace, Roche, Jacobi, Lord Kelvin, Poincaré, and Darwin, giving at the same time a resumé of what has been done previously in this line of research.

Four simplified models of astronomical matter have been studied:

A. The incompressible model, consisting of a mass of homogeneous, incompressible matter of uniform density.

B. Roche's model, consisting of a point nucleus of great density, surrounded by an atmosphere of negligible density.

C. The generalized Roche model, consisting of a homogeneous, incompressible mass of finite size and of finite density surrounded by an atmosphere of negligible density.

D. The adiabatic model, consiting of a mass of gas in adiabatic equilibrium.

The models *A* and *B* are the extreme cases of *C* and *D*. The model *C* goes over into the models *A* and *B* as the atmosphere becomes very small or very large relative to the nucleus. The model *D* goes over into *A* and *B* as γ, the ratio of the specific heats at constant pressure and at constant volume, changes from infinity to 1.2.

If the models are subject to rotation alone, the mechanism of breaking up is quite different for the types *A* and *B*. For model *A* the original spherical form, which the matter must have as a result of its own gravitation if there is no rotation, will first change into a spheroidal form, which, with increasing angular rotational velocity (as the body contracts), changes into an ellipsoidal figure, the smallest axis of course being parallel to that of rotation. With still higher rotational velocity a furrow will form across a section of the ellipsoid, producing Poincaré's pear-shaped configuration. This configuration is now proved by Jeans to be unstable, and thus, when the furrow once has started, the breaking up of the body into two detached parts takes place.

The model *B*, when subject to rotation, evolves into a lens-shaped figure with sharp edge, from which matter is continually ejected as the velocity is increased. In the more general cases *C* and *D*, one of these two methods of breaking up must occur when the rotational velocity exceeds a certain value.

These two methods of breaking up—fission, and ejection from the equatorial belt—are considered to be the only ones possible in a gaseous body subject to rotation. If tidal forces are present the ways of breaking up are the same as those mentioned before, but the ejection of matter from the equatorial belt is now confined to definite points on the equator.

This theoretical result is in very good harmony with observations of spiral nebulae. The lenticular form is obvious in such nebulae as N. G. C. 3115 and 5866, and many others. Even a very slight gradient in the gravitational field produced by outside bodies would give rise to tidal forces strong enough to force the matter to be ejected from two opposite points, instead of uniformly all around the equator. This condition would produce a spiral nebula with two opposite arms of ejected matter.

Another consequence of the theory is that if a nebula, or gaseous body in general, has shrunk from an approximately isothermal condition to one in which there is a rapid temperature gradient from surface to center, the angular velocity would increase as we pass from the center outwards, supposing of course that the viscosity is insufficient to produce a rotation as a solid body. This gives us a natural explanation of the acceleration of the Sun's rotation at the equator; and also of the slight increase in rotation with distance from the center which can be found in Pease's measurements of the velocities in the *Andromeda* nebula, altho in most cases observation shows that the spiral nebulae rotate as solid bodies.

The theory gives reason to believe that the equatorial breaking up of a contracting nebula is a continuous process, not a periodic one as Laplace and Roche imagined; and further, that the breaking up is cataclysmic, since the ejected matter itself provides a force tending to increase the rate of ejection of matter. Jeans finds that the nuclei in spiral nebulae are comparable in mass with the Sun, and that a nebula such as that in *Andromeda* may be as massive as the whole galactic system!

The probable result of the disintegration of a spiral nebula, according to Jeans, is a star cluster, the numerous nuclei forming individual stars. Such an evolution is not derived mathematically, to be sure, but is rather an hypothesis which has several observational facts in its favor. The comparability in size and mass between spiral nebulae and star clusters is especially emphasized by Jeans. There are, however, several dissimilarities between these two celestial objects—the star clusters are few in number and have a different distribution in space, and further, the spirals are much more flattened than the star-clusters. The real connection between these two kinds of objects is thus still an open question.

A special chapter has been devoted to the stellar motions in the galactic system. In agreement with all other investigators, Jeans finds that the effect of encounters, and still more of actual collisions of stars, is very slight, owing to the large distance between the stars. It is thus permissible to study the motions of the stars by means of the kinetic theory of gases with collisions left out. Jeans finds now that in a flattened system which has originated out of a rotating nebula, the only steady type of motion is one where the stars are moving in circular orbits around the center of the system. This seems to him to be the interpretation that agrees best with the observational results of Kapteyn's star streams.

A difficult problem is encountered when we look for an explanation of the correlations between spectral type and absolute magnitude, and spectral type and velocity in space. The stars of earlier types have smaller velocities than those of later types, and for stars of the same type, those of high luminosity move more slowly than absolutely fainter stars. An equipartition of energy cannot take place in the present state of the galactic system, the distances between the stars being too great. The suggestion is made that a partial equipartition of energy took place when the system was considerably smaller and the stars more closely packed.

The theory is favorable to the idea of the stars originally becoming hotter by contraction and later on losing heat by radiation. This is in harmony with the evidence found for giants and dwarfs, the giant M stars being in a state nearest the origin. It is supposed, however, that only the most massive stars attain the B type spectrum.

The author finds it somewhat difficult to explain the evolution of binary stars. A certain lower limit of density is required to account for the breaking up of a star by fission. This limit is set at about one-fourth that of water, and as most giant stars have smaller densities it is difficult to imagine fission due to rotation alone. The dependency of period and the orbital eccentricity of binaries upon spectral type admits, according to Jeans, of no answer as long as the binary is regarded as a self-contained system. Stellar enocunters, however, have the tendency to increase the eccentricity, linear dimension, and period of an orbit. After a large number of stellar encounters the eccentricities will group themselves around the mean value ⅔, while the periods will depend on the mass of the star, being of the order of a year for a star of mass 1.7 times the Sun. In order to reconcile this with the observed distribution of periods and eccentricities we have to assume that the B-type binaries were the last to be born, when the chances of close encounter were rare.

The evolution of the present solar system, which probably is an exception among the stars as the companions are all of very small mass compared with the central body, can only be the result of the passing of a massive star close by the central body, the latter then throwing out jets of matter towards the passing star. Condensations in these jets later on formed the planets.

The book contains many original investigations of a theoretical character by the author, and throws light on numerous problems which are of especial interest to the practical astronomer.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1920

By Malcolm McNeill

PHASES OF THE MOON, PACIFIC TIME

Full Moon....	March	4,	1^h13^m P.M.	Full Moon......	April	3,	2^h55^m A.M.
Last Quarter..	"	12,	9 57 A.M.	Last Quarter...	"	11,	5 24 A.M.
New Moon....	"	20,	2 56 A.M.	New Moon.....	"	18,	1 43 P.M.
First Quarter..	"	26,	10 45 P.M.	First Quarter...	"	25,	5 27 A.M.

The vernal equinox, the time when the Sun crosses the equator from south to north, occurs March 20, 2 P. M. Pacific Time.

Mercury on March 1st is an evening star, setting not quite an hour and a half after sunset. It reaches greatest east elongation on March 3rd. As it passed perihelion on February 29th, only four days before, the elongation, 18°12′, is much smaller than the average greatest elongation and its motion toward inferior conjunction is quite rapid. It reaches this point about midnight on March 19th. It will be easily visible in the evening twilight on March 1st, but its rapid approach to the Sun permits naked eye view for only a few days. After inferior conjunction it becomes a morning star and moves out toward greatest west elongation, reaching this point, 27°31′, on April 16th. This is much larger than the average, since the planet reaches its aphelion on April 13th. However, as the planet is 12° south of the Sun, it will rise less than an hour before sunrise and the conditions for visibility are not good. It is in conjunction with *Venus* on April 4th; but the planets are then too near the Sun for easy visibility altho possibly *Venus* may be seen on account of its superior brightness.

Venus is still a morning star, but the apparent distance from the Sun diminishes. On March 1st it rises a little less than an hour and a half before sunrise and during the two months' period this interval diminishes to about half an hour. The great brilliancy of the planet, however, will permit naked eye view thru nearly all this period. It is in conjunction with *Uranus* on March 20th, passing 0°21′ south of the latter.

Mars rises on March 1st at about 10:30 P. M. and on April 30th a few minutes before sunset. It reaches opposition with the Sun at 1 A. M. April 21st Pacific Time. The present period is the best for view of the planet since the last opposition, March, 1918. The present opposition is about an average one in point of distances from the Earth and Sun, and consequently the brilliance of the planet is better than the last two and not as good as the next two, especially the second following, which will correlate in August, 1924.

The planet will then be at nearly its least distance from both Sun and Earth. At the present opposition on April 21st the planet will be distant from the Earth about 54,000,000 miles. The time of least distance is about one week after opposition, but the variation in distance is too small to make any appreciable difference in its appearance. All thru the period the planet will be brighter than any of the fixed stars except *Sirius*, and will nearly reach that star's brightness for a few days near opposition. *Mars* is in *Libra*, and moves eastward about 1° up to March 14th; during the rest of the period it retrogrades, moves westward, about 12° and northward about 3° to about the boundary of *Libra* and *Virgo*.

Jupiter is in fine position for evening observation thruout March and April. On March 1st it is about three hours high at sunset and on April 30th it is already past the meridian. It does not set until nearly sunrise on March 1st, and on April 30th it remains above the horizon until after 1 A. M. It is in *Cancer* and retrogrades, moves westward, about 2° until April 3rd; it then resumes its eastward motion, making about 1° up to the end of the month. Thruout the two months it is very close to *Neptune*, coming to conjunction with the latter twice, the first time on March 12th when *Jupiter* is moving westward and the second time, April 19th, when it is moving eastward. At each conjunction *Neptune* is slightly less than 1° south of *Jupiter*.

Saturn is in the same general quarter of the sky as *Jupiter*, following after it somewhat more than an hour's motion. It passed opposition with the Sun on February 27th and was then above the horizon thruout the entire night. On April 1st it is about three hours high at sunset, and on April 30th it is about one hour east of the meridian at sunset. On the latter date it does not set until about half after two A. M. It is in *Leo* and retrogrades, moves westward, about 3°, and 1° northward during the two months, having nearly reached the limit of its westward motion at the end of April. As seen in the telescope the rings are narrower than they were during 1919, and by the end of the year they will look like a mere line. During the first part of the year they will widen a little until the minor axis is about 15 per cent of the major during April, but after that the diminution will be rapid.

Uranus passed conjunction with the Sun on February 21st, and became a morning star, but remains too close to the Sun for naked eye visibility during March and April.

Neptune passed opposition with the Sun at the end of January. Its proximity to *Jupiter* has been mentioned.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE MOTION IN SOME A DOUBLE STARS

FIFTH NOTE

During the year 1919, the remeasurement of the double stars of my own discovery continued to form the main part of my observing program. Of the pairs A 1 to A 2500 only 83 now remain without any measures at a second epoch; about 150 others have been remeasured on one or more nights but are kept on the observing program for further measures. Nearly 25 per cent of the pairs remeasured during the year have shown change in angle, or distance, or both, in the interval since discovery, which appears to be greater than can be accounted for by errors of observation. The change in the majority of these pairs is doubtless due to orbital motion. Twenty-two of the most interesting of these systems are listed in the following table, which is similar in its arrangement to the tables in my earlier notes.

Star	Δ epoch	ΔO	ρ disc.	Δρ	Mags.
A 217	18ʸ.1	+24°.1	0″.17	−0″.02	8.8—8.9
A 218	18 .1	−20 .4	0 .17	+0 .07	8.4—8.5
A 513	15 .3	−29 .9	0 .42	+0 .04	9.0—9.2
A 655	14 .6	+23 .4	0 .28	+0 .06	8.2—8.5
A 1092	14 .2	−28 .4	0 .28	+0 .05	9.5—9.7
A 1256	11 .9	+15 .4	0 .13	+0 .02	7.2—7.4
A 1544	11 .5	−36 .1	0 .16	+0 .04	9.2—9.2
AB & C	10 .2	− 2 .2	1 .33	−0 .06	—10.5
A 1609	11 .9	+34 .6	0 .40	+0 .05	8.5—8.5
AB & C	11 .9	+ 6 .0	2 .14	+0 .28	—13.0
A 1614	12 .0	+45 .5	0 .29	+0 .07	9.0—9.1
A 1621	11 .6	+ 8 .5	2 .23	+0 .27	8.5—13.5
A 1737	11 .4	−19 .7	0 .31	−0 .02	9.3—10.1
A 1746*	11 .7	+30 .0	0 .18	±0 .00	8.0—8.0
A & BC	10 .7	+ 1 .4	5 .69	±0 .00	6.7—
A 1913	10 .8	−20 .8	0 .22	±0 .00	9.6—9.6
A 1968	10 .7	−23 .7	0 .29	−0 .01	9.5—9.7
A 1971	11 .0	−33 .2	0 .35	+0 .16	9.1—9.2
A 2013	9 .5	−35 .5	0 .23	+0 .20	9.5—9.5
A 2030	9 .6	−32 .7	0 .31	+0 .05	9.2—9.3
A 2080	9 .4	+15 .9	0 .24	−0 .03	8.5—8.5
A 2131	8 .6	+44 .6	0 .32	−0 .01	7.0—8.2
AB & C	9 .0	− 1 .0	38 .79	+3 .97	—13.0
A 2210	9 .2	+ 8 .1	5 .06	−0 .20	7.4—13.7
A 2329	8 .0	−11 .9	0 .38	+0 .22	9.1—9.2
A 2462	7 .0	−68 .5	0 .22	−0 .07	9.5—9.5

There are many pairs in this and in the four preceding lists in which the two components are of equal brightness and the quadrant therefore indeterminate. In every such instance, if measures at but two epochs are available, I have taken the quadrants which give the smaller of the two possible values of the apparent angular motion. Doubtless this is the correct interpretation in the majority of cases; but it is not at all improbable that in some of these pairs the larger value corresponds to the true motion. Further, it is possible that, in an occasional pair having components of equal brightness, the actual motion is one-half of a revolution or even a whole revolution altho the measures at the two epochs seem to indicate no change whatever.

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*A 1746 is the fainter component of the Struve pair Σ 1224. The Berlin A. G. Catalog gives the two components of the Struve pair slightly different proper motions; but the micrometer measures do not confirm this. The very small change noted in the last 100 years is probably due to slow orbital motion.

For example: The discovery measures, in 1902, of A 417 (= 83 Aquarii) gave the position, 61°.0, 0″.19, and those of A 88, in 1900, the position 353°.2, 0″.14, the components in each pair being of equal brightness; in 1919, my measures gave, respectively, 355°.2, 0″.15 and 188°.4, 0″:15. If measures in intermediate years were lacking it would be natural to assume retrograde motion in the former pair and an angular change of 66° in the 17 years; and, in the latter pair, direct motion with an angular change of but 15° in the 19 years. As a matter of fact, I have measured each pair annually, and these measures show that the observed motion in A 417 now amounts to 294°, the period of revolution being approximately twenty-four years, and that A 88 has made one and one-half revolutions since discovery, the period being 12.1 years.

These remarks may have an application to the case of the pair A 1746 AB entered in the table above. My measures in 1908 gave 140°.07, 0″.19; two accordant measures last month gave 170°.7, 0″.19, an apparent change of just 30° in the 11.7 years, as entered in the table. But measures on one good night in December, 1917, gave 139°.7, 0.″21. It is of course possible that I misread the micrometer on that night; but it is at least equally probable that the pair is in very rapid motion and that the change since discovery amounts to more than half a revolution. Measures in the latter part of this year will settle the question.

The angular separation of the majority of pairs listed above is very small. The decided increase observed in the separation of the components of A 1971, A 2013 and A 2329 probably means that the average angular motion in these pairs is greater than that indicated in the table. In the wider pairs A 1621, A 2210, and A 1609 AB & C, the change may be due to proper motion of the brighter component. There are not enough meridian observations to decide this point. The binary pair A 2131 AB and its optical companion (= Ho 357) form the subject of a note in an earlier number of these *Publications*.[1]

January 2, 1920. R. G. AITKEN.

THE MICHELSON INTERFEROMETER METHOD FOR MEASURING CLOSE DOUBLE STARS

In the PUBLICATIONS for October, 1919, Mr. Hale describes observations made by Michelson and himself, using the interferometer with the 100-inch telescope. In order to apply the method to the measurement of close double stars, a simple apparatus with movable slits was constructed and a preliminary trial made on the night of December 30th by Mr. Pease and the writer.

The slits were about 4.5 mm. wide and 25 mm. long, and were mounted about 117 cm. inside the Cassegrain focus. The diameter of the cone of light at this point being about 73 mm., the arrangement was such that the slits could be separated by this amount. The apparatus carrying the slits could be rotated about the optical axis of the telescope, for determination of position angle. The fringes were observed thru an eyepiece of 1 cm. equivalent focus. With the slits at maximum separation, the fringes were found to be too close together for easy observation, so that a magnification three or four times greater is desirable, say a power of 50 to 100 diameters. Since the focal length of the Cassegrain combination is 1600 inches = 4060 cm., this would correspond to a telescopic magnifying power of 8000 to 16,000.

Algol (*β Persei*) was first observed. The fringes were fully visible for all distances and position angles of the slits. With the spectroscopic binary *Capella*, it was at once evident that the visibility changed with the position angle. The minimum distance between the slits, for which the visibility of the fringes is lowest (practically zero in this case), was found to be 38.7 mm., in position angle 148° (possibly $148^\circ + 180^\circ$). Reduced to angular measure in accordance with the simple theory, this minimum distance gives $0''.042$ as the separation of the components on December 30, 1919.

The object of the observations on December 30th was primarily to see whether the method can be applied to the measurement of double stars, and to form some idea of just how an apparatus for this purpose should be constructed. As the method is evidently applicable, the apparatus is being constructed as rapidly as possible, so that regular observations may be undertaken.

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[1] *Publ. A. S. P.*, **31**, 197, 1919.

The method appears to possess the following advantages:

1. The resolving power of the telescope (for double stars) is at least doubled.
2. Good seeing does not appear to be important, as the fringes were very sharp under poor atmospheric conditions.
3. Very small angular separations can be measured with an accuracy at least as great as that for larger angles.
4. The position angle can be determined as accurately for very close doubles as for those widely separated.

J. A. ANDERSON.

THE SPECTRUM OF T TAURI

The spectrum of the variable star T *Tauri*, associated with Hind's variable nebula N. G. C. 1555, has been discussed before in these PUBLICATIONS[1] by Adams and Pease on the basis of a spectrogram whose scale is 4.1 mm. from K of calcium to Hβ. The spectrum has now been photographed with the one prism spectrograph attached to the 100-inch reflector. The scale is 26.2 mm. from K to Hβ. An exposure of 5^h30^m gave a sufficiently strong continuous spectrum to make possible the measurement of absorption lines as far to the violet as λ 4134. When photographed, T *Tauri* was probably not brighter than visual magnitude 10.

Thirty-five absorption lines give a radial velocity of + 29 km/sec. Many other lines remain to be identified, but the foregoing are among the strongest. The strong absorption lines of iron are mostly of Class III in the electric furnace. The three lines λ 4250, λ 4260, and λ 4271 show this characteristic in a rather striking manner. The arc lines (in the comparison spectrum) λ 4250 and λ 4271 are each a blend of two lines, the violet component in each case being a line of Class III and the red component a Class II line; λ 4260 is a single Class III line. In all three cases the stellar lines give consistent displacements if only Class III lines are considered. The three strong chromium lines λ 4254, λ 4274, and λ 4289 are present. Numerous calcium lines are found—that at λ 4227 being very strong with a width of more than 5 A.

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[1] *These Publications*, **27**, 133, 1915.

The emission lines reported by Adams and Pease are confirmed for the most part by this spectrogram. In the table which follows are given: (1) wave-lengths of bright lines on my spectrogram; (2) wave-lengths by Adams and Pease; (3) corresponding wave-lengths in *η Carinae*[2]; (4) remarks.

BRIGHT LINES IN T TAURI

(1) Sanford λ	(2) Adams and Pease λ	(3) η Carinae λ	(4) Remarks
......	3889	......	Hζ
3934.1	3933	......	K of calcium
3969.8	3969	......	H of calcium
......	4066	......	Not identified
4102.0	4102	4101.9	Hδ
......	413	......	Not identified
......	419	......	Not identified
4233.4	4231	4233.3	Enhanced iron line
4340.4	4341	4340.6	Hγ
......	4470	......	He. Not confirmed
	4516	4515.4 4520.5 4522.7	Probably λ 4516 corresponds to a blend of three lines in η Carinae. There are maxima at this point on my plate, but they are unfit for measurement.
4549.7	456	4549.6	Enhanced iron line
4584.0		4584.0	Enhanced iron line
4629.5	463	4629.5	Enhanced iron line
4861.5	4861	4861.5	Hβ
4924.1	4923	4924.1	Enh'd iron line } Focus falls off badly here.
5019.5	....	5018.6	Enh'd iron line

This plate is not strong enough to decide the reality of the bright lines λ 3889, λ 4066, λ 413, λ 419, listed in the second column. The first two, however, appear upon a low dispersion spectrogram taken by the writer on October 5, 1918; λ 4470 of helium is not confirmed, and the probable identification of 4516 is indicated in the table. The enhanced iron lines given in the table are among the very strongest enhanced iron lines, both in the laboratory spectra and in *η Carinae*. An examination (after measurement) indicates the probable presence of still other enhanced iron lines, revealed by slight maxima in a continuous spectrum almost strong enough to blot them out. None of the emission lines in the first column is narrow. The mean width of the five lines, H and K of calcium, Hδ, Hγ, and Hβ is between 3 and 4 A. The radial velocity as derived from the bright lines in the first column (except the last, which is badly out of focus) is + 23 km/sec. The range in values for the individual bright lines is greater than for the absorption lines, so that it is unlikely that the difference between the values (6 km/sec.) has any meaning.

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[2] *Lick. Obs. Bull.*, **8**, 55, 1913.

In this connection it is of interest that King has produced with the electric furnace a continuous spectrum upon which are found bright H and K, λ 4227 as a strong absorption line, and the red components of the iron doublets λ 4250 and λ 4271 suppressed while the blue components show as absorption lines.

It is to be noted that η *Carinae* and T *Tauri* are both variable stars associated with nebulae. T *Tauri*, however, gives a relatively strong continuous spectrum, quite in contrast with η *Carinae*, in which the continuous spectrum, if existent, is excessively weak.

Because of the greater dispersion of this plate, the larger number of lines considered, and the agreement between the velocities from absorption and from emission lines, the radial velocity here derived may be considered to supplant velocities derived with the small dispersion hitherto used. Similar plates will be necessary to determine the constancy or variability of this velocity.

R. F. SANFORD.

OBSERVATIONS OF BARNARD'S VARIABLE NEAR MESSIER 11

On Mr. Shapley's photographs of Messier 11 the following measures have been made of Barnard's variable No. 1 (*Pop. Ast.*, **27**, 485, 1919; *Ast. Jour.* **32**, 102, 1919). The observations in July, 1916, suggest a fairly rapid increase in brightness, but the material is not yet sufficient to estimate the length of period.

Date	Photographic		Photovisual		Color Index
	Magnitude	No. of Plates	Magnitude	No. of Plates	
June 6, 1915	>16.7	1	>14.9	1	.....
June 7, 1915	16.7	1	>14.7	1	.....
July 6, 1915	15.6	1	.....	..	.....
Aug. 12, 1915	16.8	1	14.5	1	+2.3
Aug. 16, 1915	16.8	1	14.6	1	+2.2
Sept. 7, 1915	....	..	>15.0	1	.....
Oct. 3, 1915	>16.7	1	....	..	.....
July 5, 1916	15.9	2	13.3	2	+2.6
July 6, 1916	15.6	3	13.3	2	+2.3
July 8, 1916	15.0	1	13.1	1	+1.9
April 19, 1917	16.1	1	....	..	.....
Aug. 14 1917	15.2	2	....	..	.....

Barnard's variable No. 2 does not appear on any of these plates, nor is it on the spectral plates made with the 100-inch telescope on September 14, 15, and October 1, 1919, which show stars as faint as 13.9, 15.6, and 15.6, respectively. MARY RITCHIE.

NOTE ON THE PARALLAX OF CEPHEID VARIABLES

In his study of the distances of globular clusters (*Mt. Wilson Contribution*, No. 151) Shapley gives a table comparing the trigonometrically determined parallaxes of six Cepheid variables with values derived from the period-luminosity curve. A revision of the comparison is now possible since a few additions to the material are at hand, and, moreover, Miss Coral Wolfe and the writer have recently determined the systematic errors in the trigonometric parallaxes of different observers. The result of the study of the systematic errors will be published shortly in another place.

The following table gives in successive columns: the number of the star in Boss's *Preliminary General Catalogue*, the parallax observers, the absolute parallax with its probable error, the same values corrected for systematic error, and the parallax as derived by Shapley in *Mt. Wilson Contribution*, No. 153.

Boss Number	Observer	π abs.	p.e.	π Corrected	p.e.	πShapley
325	Several..........	+0″.028	±0.015	+0″.028	±0.015	+0″.016
637	van Maanen.....	+0 .010	5	+0 .009	5	+0 .004
1629	Miller, v. Maanen	+0 .026	15	+0 .022	12	+0 .004
1815	Abetti, Miller, Alleghany.......	+0 .013	6	+0 .006	4	+0 .004
5071	Mitchell.........	+0 .004	9	+0 .003	9	+0 .005
X Cygni	Miller...........	+0 .005	9	−0 .005	9	+0 .001
5532	Yerkes..........	−0 .011	9	−0 .006	9	+0 .018

The mean of the seven trigonometrical parallaxes is + 0″.011. After the application of the systematic corrections this mean value reduces to + 0″.008, in exact agreement with the value derived by Shapley from the period-luminosity curve. A. VAN MAANEN.

THE PARALLAX OF NOVA AQUILAE NO. 3

In these PUBLICATIONS for August, 1919, Sanford and the writer published a preliminary parallax of *Nova Aquilae* No. 3; the result was partly based upon exposures taken on June 12, 1918, which showed images of the nova of 6″ diameter, notwithstanding the fact that a double rotary sector had been used. Several better plates were secured later and the result of the measures of 16 exposures of good quality give as the relative parallax

$$\pi = +0''.019 \quad \pm 0''.006$$
$$\mu_a = +0''.025 \quad \pm 0''.012$$

The absolute parallax is +0″.021. Accepting the apparent magnitude at maximum as −1.5 and at minimum +10.5 (*Harvard Circular*, No. 208), we find for the absolute magnitude −4.9 and +7.1 respectively

A. VAN MAANEN.

A SEVENTEENTH NOVA IN THE ANDROMEDA NEBULA

This object is situated 15″ east, 150″ north of the nucleus, and is surrounded by soft nebulosity. It appears on plates taken by Shapley in October, and is invisible on earlier and later plates by Sanford and Shapley.

ESTIMATED MAGNITUDES

September 21, 1919	invisible
October 15, 1919	invisible
October 16, 1919	invisible
October 30, 1919	15.7
October 31, 1919	16.5
November 30, 1919	invisible
December 18, 1919	invisible

No. 17 is nearer the center than any nova found in the *Andromeda* nebula since the discovery of No. 1 in 1885, and in recorded maximum brightness exceeds all but No. 1. The change of magnitude is uncommonly rapid for the descending branch.

MILTON HUMASON.

NEBULAR LINES IN THE EXTREME RED

In a preliminary attempt to explore the near infra-red spectra of the gaseous nebulae, the spectrum of the planetary nebula N.G.C. 7027 has been photographed with plates bathed in dicyanin. Four lines, which appear not to have been previously reported, have been found in the extreme red. Their wave-lengths are approximately 7009, 7065, 7138, and 7325 A. Of these the second is doubtless due to helium, while the origin of the others is unknown.

The instrumental equipment used in this preliminary work was the 36-inch refractor with a spectrograph carrying a single 60° prism and a camera of 6 inches focal length, ratio F/4. By reason of these optical dimensions the scale of the spectrograms is small, a millimeter being the equivalent of about 600 A. Under normal conditions of adjustment for the visible region of the spectrum the definition given by this instrument is excellent as far as 6800 A, where, however, it begins to fall off; it was therefore necessary in these observations to adopt a mean focus for the region sought to be photographed, which lies beyond that limit, and a focal setting was found which gives fair, tho not perfect, definition from 6700 to 8500 A.

The observations were made on November 20, 1919, with an effective exposure of about an hour, and on the following night with an exposure of six hours and twenty minutes. The first of these exposures was interrupted by clouds and was only partially successful. The measures are of the second plate. The wave-lengths resulting from the measures are given in the first column of the accompanying table. The second column records intensities roughly assigned on a system which would rate the strength of Hα at 100. Two of the faint lines (668 and 673 $\mu\mu$) had previously been measured with apparatus of greater dispersion, and a third (706 $\mu\mu$) may be assumed to be due to helium. These three lines indicate a systematic error of about -4 A, which is a surprisingly large discrepancy even with such low dispersion. The lines in question are very faint indeed, about at the limit of measurability, while the comparison lines are, on the other hand, relatively strong. That fact, taken in connection with the imperfection of focus already alluded to, would operate to produce a discrepancy of the nature of the one observed. This offers the most plausible explanation of the discordance that occurs to me, and assuming it to be the correct one, and, furthermore, that the error is less for the stronger nebular lines, I have applied to the latter a correction of $+ 2.5$ A, which gives the values in the last column of the table. These are offered as provisional wave-lengths.

TABLE OF WAVE-LENGTHS

Measured	I	Assumed Normal	Provisionally Adopted
6673.3	1	6678.2	....
6726. ±	1	6730.	....
7006.4 ±	1	....	7009 ±
7062.0	2	7065.2	7065
7135.9	10	....	7138
7322.6	9	....	7325

The line 7009 A is very faint, and while there is nothing in the appearance to suggest that it is spurious, as a weak line, photographed on only one plate, its reality is necessarily open to question.

I am indebted to the generosity of Dr. Keivin Burns for the plates on which the photographs were made Dr. Burns is at present contributing his services as a special investigator at the Lick Observatory, for the purpose of photographing various celestial spectra in the near infra-red. To his especial skill in preparing plates of extreme sensitivity to the longer wave-lengths the success of these preliminary observations is largely due.

December, 1919. W. H. WRIGHT.

PRELIMINARY NOTE ON THE VARIATION OF LATITUDE

The variation of latitude for this station can be derived from the observed motion of the pole of figure about the pole of rotation of the Earth. The coördinates of the observed rotation have been reduced, up to the epoch 1918, and have been published in various issues of the *Astronomische Nachrichten.* The discussion made here recently of this published material gives the following expression for the variation at this station, from 1890 to 1914:

$$\begin{aligned}\phi-\phi_0=+0''.02+0''.15\cos(t-1902.05)303^\circ\\ +0''.06\cos(t-1902.3)\,360^\circ,\end{aligned}$$

where t is expressed in years; and the computation has been made for every tenth of a year. The coefficient 303° corresponds to a period of 1.19 years, derived from the observed values up to 1918, with a probable error of less than ± 0.01 year. The published material includes the data from over twenty fixed observatories, and from eight international latitude stations where zenith telescope observations have been made. The average difference between the values of $\phi - \phi_0$ derived from the observed coördinates of the rotation and from the expression above is $\pm\ 0''.04$. The average value of $\phi - \phi_0$ is $\pm\ 0''.12$, which is three times the average deviation of the computed values.

The extensive investigation of the variation of latitude by Dr. S. C. Chandler resulted in an expression of the variation for a station in longitude λ of the form:[1]

$$\begin{aligned}\phi-\phi_0=-0''.16\cos[\lambda+(t-2411790)0^\circ.85]\\ -r^2\cos(\odot-G),\end{aligned}$$

where t was given in days. The expression consists of two terms, one having a period of 427 days (fourteen months), and the other an annual period. These terms closely resemble those derived here for the observed material up to date, except that the period of the first term has been increased to 434 days, and the coefficient of the annual term is now smaller than that derived by Dr. Chandler up to 1894, 0″.06 in place of 0″.11 for this station.

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[1] *Astr. Jour.*, **14**, 141, 1894.

The fourteen-month term was originally quite precisely 1.17 years, and the small change of two hundredths of a year when carried thru the total interval of 28 years amounts to over half a year in the computation of the values of the so-called fourteen-month term. This would result in a complete reversal of the signs of the computed variations for the fourteen-month term, since the values rise from zero to a maximum in 0.3 year, and pass from maximum to minimum in 0.6 year. This explains the discrepancy between the variation observed here with the meridian circle in 1917 and 1918, and the values of $\phi - \phi_0$ from Chandler's original formula.[2]

Taking the reduced value of the coefficient, 0°.83 in place of 0°.85 of Chandler's expression, to conform to the later data, with $\lambda = 122°$, $r_2 = 0''.11$ and $G = 197°$ for Lick Observatory, the values of $\phi - \phi_0$ for every tenth of a year have been computed up to 1918. The average difference of accidental character between the values from the observed coördinates of the polar motion and those from the revised formula is ± 0″.05. Some mean differences of a systematic character appear in the later years, when values of the z term as large as + 0″.08 are given for a single year.

The values of the latitude observed here in 1917, when compared with the expression representing the observed coördinates of the pole of figure, have an average derivation of ± 0″.08 for a group of eight nights, while the average residual from the mean ϕ is ± 0″.14 for the same groups. The latitudes observed at the international latitude station at Ukiah, in the same period, agree with the variations in the computed expression with an average deviation of ± 0″.02. The average difference of the variations, as observed at the two stations, is ± 0″.08. The differential observations with the zenith telescope are more precise than those made with the meridian circle, in which systematic errors of fundamental declinations and of refraction have more pronounced effect.

R. H. Tucker.

January 19, 1920.

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[2] *L. O. Bull.*, **10**, 36. 1919.

FURTHER NOTE ON THE COLOR CURVE OF THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY

In the February, 1919, number of these PUBLICATIONS an account was given of an investigation of the color curve of the objective of the 12-inch equatorial of the Lick Observatory. In pursuance of the plan mentioned there, we took further measures on the nights of July 16th and 17th, to obtain a more accurate determination of the temperature equation. The method of observing was the same as that described in the previous paper, and the position of the slit with respect to the base plate was measured as before. Six complete sets of measures by the Foucault method were taken, three by each observer; the mean temperature was $+ 25^\circ.0$ C. The resulting "high temperature" color curve is parallel to those for lower temperatures, with a constant difference of 1.67 mm. between this and the curve for $4^\circ.6$ C. Thus the temperature equation, as determined from a range of $21^\circ.4$ is

$$R = R_0 + 0.08 \text{ mm. } (t - 9^\circ.1),$$

which is identical with the equation obtained before from a range of 9°.

EDITH E. CUMMINGS,
PRISCILLA FAIRFIELD.

VOLUME XIII, PUBLICATIONS OF THE LICK OBSERVATORY

A few preliminary copies of Volume XIII, *Publications of the Lick Observatory*, have just been received. The entire edition is thru the press work stage and is undergoing assembly in the bindery department of the *University Press*. It is hoped that distribution of the volume to the correspondents of the Lick Observatory may be made in the month of February. The contents of the volume are as here described briefly by title and otherwise. The several manuscripts were completed at the times set down with each title.

Part I.—Descriptions of 762 Nebulae and Clusters Photographed with the Crossley Reflector, by H. D. Curtis. (March, 1918, pp. 9-42, plus 2 full-page plates.) This paper comprises brief descriptions of all photographs of nebulae made with the Crossley Reflector from 1898, when systematic work was commenced with this instrument at Mount Hamilton, until February 1, 1918.

Part II.—A Study of Occulting Matter in the Spiral Nebulae, by H. D. Curtis. (March, 1918, pp. 45-54, plus 5 full-page plates.) It is well known that certain spiral nebulae seen edgewise or nearly so, show a dark lane running lengthwise of the nebular image, an appearance generally explained as due to a band of absorbing or occulting matter. It is not so well known that many spirals viewed obliquely with reference to their principal planes show apparently related effects, in that many details of structure are fainter on one side of the apparent axis of figure than upon the other side. The plates accompanying this paper illustrate these phenomena for 78 spiral nebulae.

Part III.—The Planetary Nebulae, by H. D. Curtis. (March, 1918, pp. 57-74, plus 19 full-page plates.) All of the known planetary nebulae north of declination $-34°$ have been photographed with the Crossley Reflector as the basis for various studies of these interesting objects. There are half-tone reproductions of 78 planettaries, varying from those which are described as "stellar" up to the largest-known planetary, N. G. C. 7293. The larger planetaries are reproduced directly from the photographs, but the great majority are reproduced from Dr. Curtis's drawings based on the original negatives. Textual descriptions accompany the illustrations. The paper classifies the planetaries with reference to certain characteristic features, and treats of their apparent distribution and their forms in 3-dimensional space.

Part IV.—The Spectrographic Velocities of the Bright-Line Nebulae, by W. W. Campbell and J. H. Moore. (February 1, 1918, pp. 77-183, plus 14 full-page plates.) The radial velocities have been observed for all known bright-line nebulae except nine, which are too faint for such observations with the means at hand and with exposures of practical length. This refers to bright-line nebulae in the southern hemisphere as observed on Cerro San Cristobal, Santiago, Chile, as well as to northern nebulae observed at Mount Hamilton. The radial velocities of 125 nebulae have thus been determined. Forty-six planetary nebulae were observed at Mount Hamilton for evidences of rotation or internal motion. The observational data were used as the basis for various studies of the planetary nebulae as a class and of special studies of selected nebulae.

Part V.—The Radial Velocity of the Greater Magellanic Cloud, by R. E. Wilson. (June, 1917, pp. 187-190, plus 1 full-page plate.) Seventeen of the known 19 bright-line nebulae in the Greater Cloud were observed on Cerro San Cristobal. It is believed from the results obtained that the Greater Cloud as a whole has a high velocity of recession with reference to our stellar system.

Part VI.—The Wave-Lengths of the Nebular Lines and General Observations of the Spectra of the Gaseous Nebulae, by W. H. Wright. (July 30, 1918, pp. 193-268, plus 9 full-page plates.) Forty-eight bright-line nebulae were observed, with various spectrographs attached to the 36-inch refractor and the Crossley reflector, but chiefly with a slitless quartz spectrograph attached to the reflector. The wave-lengths of 70 bright lines in the nebular spectrum have been determined with accuracies depending chiefly upon the brightness of the lines. Special studies have been made of the distribution of the nebular materials as represented by the radiations of different wave-lengths. The nuclei of the planetary nebulae have been given careful spectrographic observation. The spectral relationships of the bright-line nebulae and special classes of stars are briefly discussed.

The volume forms one of many in the Semicentennial Series of publications issued by the University of California.

There is obvious regret that the manuscripts of these papers on the nebulae should have remained so long in the hands of the printer, but our sentiments may well be tempered by the thought of vastly greater regrets and misfortunes in the world about us. It is scarcely necessary to say that advances made in the past two years in other departments of astronomical knowledge would have modified these nebular studies in certain particulars, but it was decided to let the manuscripts stand exactly as they were at the dates appended. W. W. CAMPBELL.

January 19, 1920.

THE SIERRA NEVADA MOUNTAINS AND THE YOSEMITE VALLEY, AS SEEN FROM MOUNT HAMILTON

The frontispiece to the present number illustrates some of the advantages of the use of plates made sensitive to the longer wave lengths of light in photographing distant objects. Ordinary photographic plates, it is well known, utilize chiefly the blue and violet light rays; these rays are so scattered by atmospheric haze that distant objects appear blurred upon such plates. The present photograph was taken with a 20-inch-focus camera, using a selenium red color screen and a plate stained with krypto-cyanin, a dye recently discovered at the U. S. Bureau of Chemistry. The light of long wave-length thus employed is relatively little affected by haze or those atmospheric disturbances which cause "bad seeing"; the distant mountains therefore show almost as clearly as the nearby ridges. As noted in the title to the plate, the Half-Dome in the Yosemite Valley is 120 miles from Mt. Hamilton; the snow ridges at the extreme right in the photograph are fully 145 miles distant. The San Joaquin Valley is hidden by the low ridges in the foreground. The atmospheric conditions on the day the photograph was taken were fairly good, but not at all exceptional; the snow-capped Sierras are often even more distinctly seen from Mount Hamilton.

The series of experiments, of which this photograph is one, was initiated by Dr. Keivin Burns,[1] who has been studying the solar spectrum in the infra-red region with the 36-inch refractor and a grating spectrograph, using plates stained with similar dyes.

PUBLICATION COMMITTEE.

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[1] See his note on another page in this number.

GENERAL NOTES

The Einstein Theory of Relativity. In consequence of the very interesting results obtained by the British observers of the total eclipse of the Sun on May 29, 1919, to which brief reference was made in the December number of these PUBLICATIONS, the Einstein theory of relativity has become one of the most popular of all topics in current periodical literature, both scientific and unscientific. Many of the statements made in journals of the latter class must amaze the author of the theory; but others are of interest as expressing the bewilderment produced by the apparent demonstration of a theory which is assumed—whether correctly or not—to overthrow the accepted concepts of time and space as well as the Newtonian law of gravitation. We do not often quote poetry (?) in these columns, but the following rhyme really deserves to be copied because it expresses quite accurately (particularly in the closing lines) the state of mind of many usually well informed people. It is taken from B. L. T.'s column in the San Francisco *Chronicle* for January 8, 1920.

EINSTEIN

Twinkle, twinkle, little star,
How I wonder where you are!
'Cording to the new complaint,
Where you seem to be, you ain't.

If your light waves have a kink,
What, on earth, are we to think?
Are you here, or are you there?
You might be 'most anywhere.

Viewed from our terrestrial ball,
Some things are not there at all.
What, for instance, is Orion?
And the Bear? Perhaps, a lion!

Twinkle, twinkle, little star,
How I wonder where you are!
You are less than ever fixed;
I am more than ever mixed.

It also seems desirable to quote the closing passage from an article (too long to quote in full) in the London *Times* (reprinted in *Science* for January 2, 1920) by the author of the theory, Professor Albert Einstein.

"Thus the new theory of gravitation diverges widely from that of Newton with respect to its basal principle. But in practical application the two agree so closely that it has been difficult to find cases in which the actual differences could be subjected to observation. As yet only the following have been suggested:

"1. The distortion of the oval orbits of planets round the Sun (confirmed in the case of the planet *Mercury*).

"2. The deviation of light-rays in a gravitational field (confirmed by the English Solar Eclipse Expedition).

"3. The shifting of spectral lines towards the red end of the spectrum in the case of light coming to us from stars of appreciable mass (not yet confirmed).

"The great attraction of the theory is its logical consistency. If any deduction from it should prove untenable, it must be given up. A modification of it seems impossible without destruction of the whole.

"No one must think that Newton's great creation can be overthrown in any real sense by this or by any other theory. His clear and wide ideas will forever retain their significance as the foundation on which our modern conceptions of physics have been built."

Einstein's statement, "If any deduction from it [the theory] should prove untenable, it must be given up," is of special interest. Just above this statement he gives the only three cases yet suggested in which the theory can be subjected to test by actual observation. Let us consider these briefly.

1. The only planet orbit really available for this test is that of *Mercury*. Grant that the theory here offers an explanation of the observed acceleration of the perihelion; it is also true that there may be an alternative explanation under the Newtonian law of gravitation. Seeliger has shown that the finely divided matter in circulation about the Sun within the orbit of the Earth which is revealed to us by the Zodiacal Light may be competent to produce the observed perturbation.

2. There is no question but that the English eclipse plates show displacements of the stars at the time of the eclipse (when the stars' rays passed close to the limb of the Sun) which are in accord with the displacement predicted by the theory. It is this fact upon which all the recent notice given to the theory rests. It must be remembered, however, that the total displacements are extremely small, and that the absolutely unavoidable errors of measurement amount to a considerable fraction of the entire displacements. The observers themselves were the first to point out this fact and to urge the desirability of repeating the observations at future eclipses to secure confirmation of the present results. Then it must be noted that the displacement, if thus confirmed, may be open to an alternative explanation. So eminent an astrophysicist as Professor Newall of Cambridge (Eng.) said at the

joint meeting of the Royal Society and Royal Astronomical Society at which the eclipse results were formally announced, "I feel that the Einstein effect holds the day, but I do not yet feel that I can give up my freedom of mind in favor of another interpretation of the effects obtained. If Einstein had not existed, or had not predicted a deflection, we might have had a similar experiment made to test the presence of an extended atmosphere round the Sun, and we could have argued from the result back to the hypothesis. * * * * * I prefer to keep an open mind about interpretation."[1]

3. "The shifting of spectral lines towards the red end of the spectrum in case of light coming to us from stars of appreciable mass" has been very carefully tested in the case of the Sun. Here the magnitude of the shift required by the theory is from 50 to 100 times the error of modern measurement. In fact the predicted shift on plates taken with the powerful equipment on Mount Wilson is almost great enough to be detected, if it exists, by the unassisted eye. In spite of this, Dr. St. John's investigations at Mount Wilson and Mr. Evershed's at the Kodaikanal Observatory, agree in giving negative results. *No displacement at all corresponding to the demands of the theory were detected.*

It thus appears that while two of the tests proposed by Einstein give favorable results, each of them *may* also be accounted for on the old Newtonian theory; and that the third—and this is precisely the one best adapted to accurate and repeated measurement —gives an unfavorable answer. Recalling once more Einstein's words, "If any deduction from it should prove untenable, it must be given up," we may concur in the opinion recently expressed by a number of prominent American physicists that the theory of relativity has not yet been established. R. G. A.

January 9, 1920.

The Jubilee Number of Nature.[2] The first number of *Nature*, the well known English weekly illustrated journal of science, was issued on November 4, 1869; it is appropriate, therefore, that the issue for November 6, 1919, should be a Jubilee Number, summarizing in brief articles by eminent authorities the progress of science during the half-century of its existence. This is a most valuable number and many of the articles it contains will be of special interest to astronomers.

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[1] The *Observatory*, **42**, 395, 1919.

[2] Received in California just before Christmas, too late for notice in the December number of these PUBLICATIONS.

Sir Norman Lockyer, who founded the journal, is still its editor and it is to be hoped that he may long continue to give it the benefit of his counsel and ripe judgment, tho he contributes "Valedictory Memories" as introduction to the present number. We join in the chorus of congratulations to him and to *Nature*.

A Catalog of 1053 Stars of Large Proper Motion.[1] Dr. Max Wolf has recently published in collected form the results of his stereoscopic examination of photographic plates, in the years 1915-1918, for the detection of stars having proper motions in excess of 0.1 annually. The majority of the stars (977) in this list were found on plates of 30 regions of the sky distributed as uniformly as the available material would permit along both sides of the parallactic equator. Professor Wolf regards his examination as complete over only the central two-thirds of each plate (star images near the edges of a plate are always poorer than those nearer the center) and on this basis estimates that there may be 42,000 stars as bright as 14th magnitude (photographic) in the sky with motions as great as those here listed. The point of greatest interest in the catalog is, perhaps, the number of stars it contains which are as faint as magnitude 12. At least 10 of these faint stars are assigned annual proper motions of 1″.25 or greater, the most remarkable ones being Nos. 359 and 489, each of 13th magnitude, with proper motions of 4″.84 and 3″.04. Only about a dozen stars bright enough to be observed with the meridian circle have motions as large as these, and less than 100 stars brighter than the tenth magnitude are known to have motions as great as 1″.5. The list thus gives observational evidence in support of the belief that there are many very feebly luminous bodies among our nearest stellar neighbors.

Honors Recently Conferred Upon Astronomers. The award of the Bruce Gold Medal of this Society to Professor E. W. Brown, of Yale University, is more particularly noted upon another page. From the *Comptes Rendus* of the Paris Academy of Sciences for December 22, 1919, just received, we learn that the Lalande Prize has been awarded to Dr. V. M. Slipher, director of the Lowell

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[1] Veröff. d. Sternwarte zu Heidelberg, 7, 195, 1919.

Observatory; the Benjamin Valz prize to M. Felix Boquet, of the Paris Observatory; and the de Pontecoulant (biennial) prize to Professor A. S. Eddington of the University of Cambridge, England. Other prize awards recently announced include the Draper Medal of the National Academy of Sciences to Professor Alfred Fowler, of the Imperial College of Science and Technology, South Kensington, England, and a Royal Medal by the Royal Society of London to Professor J. H. Jeans, of the University of Cambridge, England.

The Royal Institution of Great Britain has elected Dr. W. W. Campbell, director of the Lick Observatory, to honorary membership. This is an honor held by but two other astronomers, Dr. G. E. Hale, and M. Henri Deslandres.

Telescope for Sale. Mrs. Edward Gray, 2731 Regent Street, Berkeley, Calif., offers for sale a 9-inch (Brashear) reflector mounted in a metal tube 6 feet long. The telescope is equipped with driving clock, small finder, and a set of eyepieces with powers to 450; all in excellent condition. Price $1000. Further information may be obtained by writing to, or calling upon Mrs. Gray at the address given.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON JANUARY 31, 1920, AT 7.30 P. M.

There were present President Hodghead and Directors Aitken, Costa, Cebrian and Benfield.

The minutes of the previous meeting, as printed in the PUBLICATIONS for December, were approved.

The following new members were elected:

F. A. FANCHER,
PROF. A. M. NEWBEGIN,
THEODORE THORHAMMER,
DR. EVELYN ABBT,
M. J. VOUTE,
HAMILTON M. JEFFERS,
MISS PERSIS H. COLEMAN
and
THE DIRECTOR OF THE OBSERVATORY OF STRASBOURG, FRANCE.

The Secretary read a letter from Professor B. Baillaud, Director of the Observatory of Paris, explaining the failure of the Paris Observatory to nominate for the November award of the Bruce Medal and reiterating his kindly interest. The failure was apparently due to some miscarriage of the mails.

Referring to the action of the Board of Directors, at the special meeting of November 29th, to consider the award of the Bruce Medal, the Secretary announced that the award went, by unanimous vote, to Professor E. W. Brown of Yale University, and that same had been accepted by Professor Brown.

The following correspondence was read:

SAN FRANCISCO, CALIF., December 2, 1919.

PROFESSOR E. W. BROWN,
Yale University,
New Haven, Conn.

DEAR SIR:—

It is the very pleasant duty of the undersigned to inform you that, at a meeting of the Board of Directors of the Astronomical Society of the Pacific, held in San Francisco on the 29th ultimo, to consider the award of the Bruce Gold Medal for the year 1920, the choice fell upon you by unanimous vote—such action being in recognition of your distinguished services to the science of astronomy.

For your information, we are enclosing to you herewith a copy of the By-Laws of this Society which include the statutes for the bestowal of the Bruce Medal. Your particular attention is directed to the provisions of Article V, at the bottom of page 6, which defines the methods by which decisions of the Board are reached. All awards are based upon nominations made by the Directors of the six great observatories of Harvard, Yerkes, Lick, Greenwich, Paris and Cordoba. In making its selections the Board is, therefore, influenced by the advice of those most competent to judge.

The tender to you, on this occasion, of the Bruce Medal, will constitute the fifteenth award of same. Other recipients have been as follows: -

Simon Newcomb, Arthur Auwers, David Gill, G. V. Schiaparelli, William Huggins, W. C. Vogel, E. C. Pickering, Geo. W. Hill, J. H. Poincaré, J. C. Kapteyn, O. Backlund, W. W. Campbell, Geo. E. Hale and E. E. Barnard.

In asking the privilege of adding your name to this distinguished roll of honor, it is the conviction of the Board of Directors of the Astronomical Society of the Pacific that the distinction is one to which your merits most eminently entitle you.

The Board will appreciate an early reply from you, signifying your acceptance of the Medal and, in the mean time, we remain

Most respectfully yours,
BEVERLY L. HODGHEAD, *President.*
D. S. RICHARDSON, *Secretary.*

YALE UNIVERSITY, December 9, 1919.

MR. D. S. RICHARDSON,
Secretary of the Astronomical Society of the Pacific.

DEAR SIR:—

Your cordial letter of December 2 reached me last night.

I appreciate very highly the honor which the Board of Directors of the Society proposes to confer on me by the award of the Bruce Medal. I have long been aware of the distinction which is implied in such an award, not only on account of the care with which the selection is made, but also because of the justifiable pride which an astronomer may feel in seeing his name added to so distinguished a list as that of the past recipients of the Medal.

It is particularly pleasing to me that the honor should come just as this time when the printing of my Tables of the Moon has been completed and the volume is about to be issued, thus bringing to a conclusion the work which has been the chief occupation of my life.

It is hardly necessary to add, except as a matter of form, that I shall accept the Bruce Medal with very great pleasure.

Yours very truly,

ERNEST W. BROWN.

President Hodghead, who had just returned from the East, reported that he had had an interview with Professor Brown at New Haven, and that he had extended an invitation to him in the name of the Society, to come to California in March next to receive the Medal and address the Society. The matter is now under consideration by Professor Brown and hopes are entertained that he may find it possible to come West at the time stated.

Adjourned.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, SAN FRANCISCO, CALIFORNIA, ON JANUARY 31, 1920, AT 8.00 P. M.

President Hodghead in the Chair. The Minutes of the annual meeting of last year were approved as printed in the PUBLICATIONS of February, 1919.

Director Aitken, of the Publication Committee, made a verbal report on the work of his committee during the past year and invited attention to the fact that the Society must be prepared to meet increased costs of printing during the current year. He also directed attention to the growing prestige of our PUBLICATIONS in the scientific world, as evidenced by numerous complimentary reviews in other journals and the frequent quotations from our columns.

In response to the call for a report from the Finance Committee, and in the absence of the Chairman of that Committee, the Secretary-Treasurer presented the following report:

REPORT OF THE SECRETARY-TREASURER FOR THE FISCAL YEAR ENDING JANUARY 31, 1920

The present membership of the Astronomical Society of the Pacific is as follows:

Life Members	76
Active Members	210
Institutional Members	50
Total	336

The Society also sends its PUBLICATIONS to 34 Exchanges and to 63 Corresponding Institutions. There are 433 names upon its mailing list.

During the past year 24 new members have been added to the rolls of the Society. There have been 9 deaths, 5 resignations and 10 names have been dropped for continued non-payment of dues. Among the deceased are the names of Andrew Carnegie, Professor E. C. Pickering, Mrs. Phoebe A. Hearst, H. C. Frick, Louis Lisser, John A. Cook, James K. Lynch, Jesse W. Lilienthal and L. A. Thompson.

During the year three open meetings were held, the first on March 29th, in San Francisco, when Dr. W. W. Campbell, Director of Lick Observatory, spoke on the subject: "What are the Spiral Nebulae?"

The second lecture was given by Dr. George E. Hale, Director of Mount Wilson Solar Observatory, in Berkeley, July 7th, his subject being: "The Work of the Amateur Astronomer."

The third lecture was given by Dr. R. G. Aitken, of Lick Observatory, at the Students Observatory, Berkeley, on the evening of November 29th, his subject being: "Island Universes; what we know about them."

The marked feature of the Society's activities during the past year has consisted of the publication, in book form, of the twelve Adolfo Stahl Lectures in Astronomy which were delivered in San Francisco during the seasons of 1916-17-18, under the auspices of the Society. This work was made possible by the generosity of Mr. Adolfo Stahl, who not only paid for the publication of the book, but who has turned over to the Society all revenues derived from its sale. One thousand copies of the book were printed, about one-third of which have already been sold, netting to date approximately $600, which is now available to the Society for other astronomical work. Next to Mr. Stahl the principal credit for this undertaking is due to Dr. Aitken, Chairman of the Publication Committee, whose arduous and unselfish labor in editing the work is entitled to grateful recognition. The work is already receiving wide attention from scientists and learned institutions in all parts of the world.

Among other activities of the Society may be mentioned its participation in the work of the Pacific Division of the American Association for the Advancement of Science, which held a meeting at Pasadena, in June, at which a number of valuable papers were presented by members of the Astronomical Society of the Pacific.

At the special meeting of the Board of Directors, held on November 29th, to consider the award of the Bruce Gold Medal for 1920, the unanimous choice fell upon Professor E. W. Brown, of Yale University, and that distinguished scholar has signified his acceptance of the honor. This makes the fifteenth presentation of the Bruce Medal, its holders now constituting an enviable roll of honor. An invitation has been extended to Professor Brown to come to San Francisco in March next to receive the medal in person, and hopes are entertained that he will be enabled to address the Society on that occasion.

In this connection, it is proper to state that, at the meeting of the Board of Directors, held on March 29th last, the statutes which govern the bestowal of the Bruce Medal were amended by the substitution of the National Observatory at Cordoba, Argentine Republic, for the Observatory of Berlin, as one of the six nominating institutions for the bestowal of this medal.

The library of the Society, which is now housed in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster streets, San Francisco, is slowly growing in volume and usefulness. There are now 6567 items in the library; 635 bound and 5932 pamphlets and other unbound material. During the year 1919 665 items were added, of which 14 were bound and 651 were pamphlets and other unbound material. Thanks to the interest and constant care of the Branch Librarian, Mrs. Laura Steffens Suggett, this material is now carefully indexed and shelved and every facility is offered to those who desire to consult it.

Owing to building operations started during the year in the Lick Building, on Montgomery street, which was the former home of the Society, it became necessary to find new quarters, and the office of the Society is now located in Room 709 of the Postal Telegraph Building, at 22 Battery street, San Francisco.

Report of the Treasurer for the Fiscal Year Ending January 31, 1920

GENERAL STATEMENT

Assets:	
Thirty-one bonds (par value $20.450)—cost	$20,404.69
Cash in Alvord Fund—Savings Union Bank	218.99
Cash in Library Fund—Security Savings Bank	100.84
Cash in Life Membership Fund—Security Savings Bank	281.96
Cash in Dolbeer Fund—Union Trust Co.'s Bank	109.89
Cash in Bruce Medal Fund—First Federal Trust Co	196.24
Cash in Comet Medal Fund—Savings Union Bank	111.46
Cash in General Fund—Donohoe Kelly Bank Co	1262.12
Total	$22,686.19

Note.—The value of library, office furniture and unsold Stahl books on hand is not considered in this statement.

Liabilities, none.

STATEMENTS BY FUNDS

William Alvord Fund		
Dr. To cash balance January 25, 1919		$210.51
Interest received		301.99
Total		$512.50
Cr. By transfers to General Fund		293.51
Balance January 31, 1920		$218.99
Holds 6½ bonds—Par	$4700.00	
Cost	4570.25	

Montgomery Library Fund

Dr.	To cash balance January 25, 1919		$195.96
	Interests received		169.88
	Total		$365.84
Cr.	By transfers to General Fund		265.00
	Balance January 31, 1920		$100.84
	Holds 3½ bonds—Par	$3500.00	
	Cost	3573.75	

Life Membership Fund

Dr.	To cash balance January 25, 1919		$222.41
	Interests received		193.60
	Total		$416.01
Cr.	By transfers to General Fund		134.05
	Balance January 31, 1920		$281.96
	Holds 5 bonds—Par	$3050.00	
	Cost	3046.25	

John Dolbeer Fund

Dr.	To cash balance January 25, 1919		$301.51
	Interests received		206.89
	Total		$508.40
Cr.	By transfers to General Fund	$198.51	
	Liberty bonds purchased	200.00	398.51
	Balance January 31, 1920		$109.89
	Holds 8½ bonds—Par	$4900.00	
	Cost	4927.22	

The Bruce Medal Fund

Dr.	To cash balance January 25, 1919		$436.42
	Interests received		159.82
	Total		$596.24
Cr.	By purchase liberty bonds	$300.00	
	Medal for 1920	100.00	400.00
	Balance January 31, 1920		$196.24
	Holds 6½ bonds—Par	$3300.00	
	Cost	3287.22	

The Donohoe Comet Medal Fund

Dr.	To cash balance January 25, 1919		$ 73.16
	Interests received		38.30
	Balance January 31, 1920		$111.46
	Holds 1 bond—Par	$1000.00	
	Cost	1000.00	

GENERAL FUND—TRANSACTIONS

Dr.	To balance January 25, 1919		$ 693.34
	Alvord Fund		293.51
	Life Membership Fund		234.05
	Dolbeer Fund		223.51
	Bruce Medal Fund		271.25
	Library Fund		265.00
	Comet Medal Fund		35.00
	Stahl Lecture Fund		155.32
	Stahl Book Publishing Fund		6.21
	Sale of Publications		51.58
	Insurance Refunded		2.00
	Refunded on Reprints		110.25
	Dues received		1127.00
	Sales "Stahl Lectures in Astronomy"		675.46
	Total		$4143.48
Cr.	By Sunset Publishing Co	$1263.57	
	Knight-Counihan Printing Co	125.05	
	Salaries	325.00	
	Rents	127.50	
	Postage	108.32	
	Mercantile Trust Co—care of bonds	36.81	
	Taxes	19.16	
	Lecture November 29, 1919	25.00	
	Dues Pac. Div. A. A. A. S	10.00	
	Safe Deposit Box	5.00	

Insurance	9.03	
Lantern March 29, 1919	10.00	
Life Membership Fund	150.00	
Bruce Medal Fund	246.25	
Comet Medal Fund	35.00	
Stahl Lecture Fund	151.45	
Stahl Book Publishing Fund	81.23	
R. G. Aitken, services	100.00	
Security Savings Bank interest	2.95	
Books purchased for library	7.65	
Engraving Comet Medal	1.25	
Expressage on books	2.42	
Moving office	9.50	
Shelving and lettering on door	5.48	
University Press corrections	4.92	
Pac. Coast Paper Co.	2.88	
Wesley & Son, commissions	5.50	
Incidentals	10.44	$2881.36
Balance January 31, 1920		$1262.12

BONDS HELD BY THE ASTRONOMICAL SOCIETY OF THE PACIFIC

		Par
Blue Lakes	2	$ 2000
L. A. Gas & Electric	3	3900
Moulton	1	1000
East Bay Water	3	3000
So. Pac. Coast	2	2000
Oakland Transit	2	2000
Bay Cos. Power	2	2000
Edison Electric	2	2000
First Liberty	1	1000
Second Liberty	2	1000
Third Liberty	4	400
Fourth Liberty	2	550
Fifth Liberty	5	500
	31	$20,450

Jan. 30. '20. Examined and found correct.

Charles S. Cushing
J. D. Galloway.

Stahl Book Publishing Fund

STAHL BOOK PUBLISHING FUND

Dr.	Oct. 7, 1918	Cash received from Mr. Stahl		$1345.00
	Dec. 2, 1919	Bank interest		6.90
	July 8, 1919	Bank interest		18.03
	Aug. 26, 1919	A. O. Leuschner, reprints		20.21
		Total receipts		$1390.14
Cr.	Oct. 21, 1918	Stanford University Press	$ 50.20	
	Nov. 25, 1918	Aitken, postage	10.00	
	Dec. 12, 1918	Aitken expense acct	9.60	
	Jan. 3, 1919	Sierra Art & Eng. Co	11.42	
	Jan. 9, 1919	Barnes-Crosby Co	6.34	
	Jan. 27, 1919	Photo-Engraving Co.	26.70	
	Jan. 30, 1919	Photo-Engraving Co.	10.93	
	Feb. 4, 1919	Aitken, postage	10.00	
	Feb. 7, 1919	Photo-Engraving Co.	6.97	
	Feb. 25, 1919	Stanford University Press	200.80	
	Feb. 27, 1919	Yale University Press	12.56	
	Mar. 18, 1919	Sierra Art & Eng. Co	91.50	
	Mar. 20, 1919	Photo-Engraving Co.	8.00	
	April 3, 1919	Knight-Counihan Printing Co.	7.75	
	May 19, 1919	Carlisle & Co	13.60	
	July 9, 1919	Stanford University Press	895.05	
	July 17, 1919	Gibon's Express	6.21	
	Aug. 26, 1919	Postage	5.30	$1382.93
		Balance on hand		$7.21

BOOK STATEMENT JANUARY 31, 1920

"The Adolfo Stahl Lectures in Astronomy"

Books received from University Press		1000
Furnished to Lecturers	50 copies	
" Mr. Stahl	36 "	
" Reviewers	20 "	
" Costa	2 "	
" Aitken	1 "	
" Richardson	1 "	
" A. S. P. Library	1 "	
Sold	308 "	
On sale with Robertson	10 "	
" Paul Elder	13 "	
" Mt Wilson	24 "	
" Lick Observatory	18 "	
" Students Co-op	20 "	
For promotion purposes	6 "	
On hand	490 "	1000

The following is the report of the Comet Medal Committee:

REPORT OF THE COMET MEDAL COMMITTEE

MOUNT HAMILTON, CALIFORNIA.
January 10, 1920.

Five comets were discovered during the year 1919. One of these was an unexpected comet and the others were periodic comets whose returns had been predicted.

1919*a*- Kopff's periodic comet, observed by Wolf at Heidelberg on July 30, 1919.

1919*b*—Brorsen's periodic comet, discovered at Camp Idlewild, Vermont, on August 20, 1919, by Rev. Joel H. Metcalf. It was announced as an unexpected comet, but from the first elements, computed by Mr. Jeffers and Miss Heger, it was recognized by Leuschner to be identical with Brorsen's comet of 1847.

1919*c*—An unexpected comet discovered at Camp Idlewild, Vermont, on August 22, 1919, by Metcalf. It was discovered independently at Marseilles, France, on August 23, 1919, by Borrelly.

1919*d* --Finlay's periodic comet, observed at Kyoto Observatory on October 25, 1919, by Sasaki.

1919*e*--Schaumasse's periodic comet, observed at Nice, France, on October 29, 1919.

Fuller information concerning the discovery of these comets has been published under the title "Comet Notes" in the October and December numbers of these PUBLICATIONS.

In accordance with the statutes the Donohoe comet medal has been awarded to Mr. Metcalf for the discovery of comet 1919*c*.

Respectfully submitted.
W. W. CAMPBELL,
J. H. MOORE,
S. EINARSSON,
Committee on the Comet Medal.

NINETY-FOURTH AWARD OF THE DONOHOE COMET MEDAL

The comet medal of the Astronomical Society of the Pacific has been awarded to Rev. Joel H. Metcalf, of Winchester, Massachusetts, for the discovery of an unexpected comet on August 22, 1919.

The Committee appointed at the November meeting to make nominations for officers for the Society for the coming year presented the following report:

BERKELEY, CAL., Jan. 20, 1920.

TO THE ASTRONOMICAL SOCIETY OF THE PACIFIC:

Your Nominating Committee for this year submits the following list of nominees for the offices indicated:

FOR DIRECTORS

1. BENFIELD
2. CAMPBELL
3. CEBRIAN
4. COSTA
5. CROCKER
6. CUSHING
7. EINARSSON
8. HALE
9. AITKEN
10. MOORE
11. RICHARDSON

FOR PUBLICATION COMMITTEE

1. AITKEN
2. SHAPLEY
3. MOORE

FOR THE NOMINATING COMMITTEE
R. T. CRAWFORD, *Chairman.*

Director Cebrian announced that he would be absent in Europe during the coming year and suggested in the interest of the Society, that his name be dropped from the list of nominees in favor of some other member who would be present to serve. On motion of Director Benfield, duly seconded and carried, the name of Mr. A. L. Black was substituted for that of Director Cebrian on the list of nominations for Directors.

The Society then proceeded to elect the following as members of the Board of Directors and members of the Publication Committee for the ensuing year:

FOR BOARD OF DIRECTORS

W. W. CAMPBELL
J. COSTA
WM. H. CROCKER
C. S. CUSHING
BERNARD BENFIELD
STURLA EINARSSON
GEO. E. HALE
J. H. MOORE
R. G. AITKEN
L. A. BLACK
D. S. RICHARDSON

FOR PUBLICATION COMMITTEE

R. G. AITKEN
HARLOW SHAPLEY
J. H. MOORE

On motion of Director Costa, seconded by Director Benfield, it was decided that it is the sense of the Society that provision should be made to pay one-half of such expenses as may be incurred by Professor Brown, of Yale University, in coming to California to receive the Bruce Medal—provided that gentleman decides that he can come. It is understood that payment in question is to be made from any available funds resulting from the sale of the Adolfo Stahl Lectures in Astronomy. Assurances have been given that the other half of such expense fund will be provided from other sources to be announced later. The matter was referred to the Finance Committee.

Under the head of good of the order there was considerable discussion as to ways and means for providing a permanent fund from which to maintain a course of lectures on astronomy. Director Benfield was of the opinion that such a fund might be obtained and, on his suggestion, a committee consisting of Messrs. Benfield, Black, Costa and Cebrian was appointed by the Chair to investigate the matter and report at the next regular meeting.

The meeting then adjourned.

MEETING OF THE NEWLY ELECTED BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, IN SAN FRANCISCO, ON JANUARY 31, 1920 AT 9.00 P. M.

The meeting was called to order by Director Aitken and the Board at once proceeded to organize by electing the following officers for the year 1920:

For President	J. H. MOORE
For First Vice-President	B. BENFIELD
For Second Vice-President	J. COSTA
For Third Vice-President	A. L. BLACK
Secretary-Treasurer	D. S. RICHARDSON

Adjourned. D. S. RICHARDSON, *Secretary.*

OFFICERS OF THE SOCIETY.

J. H. MOORE	*President*
BERNARD BENFIELD	*First Vice-President*
J. COSTA	*Second Vice-President*
A. L. BLACK	*Third Vice-President*
D. S. RICHARDSON	*Secretary and Treasurer*

Board of Directors—WM. H. CROCKER, C. S. CUSHING, D. S. RICHARDSON, J. COSTA, R. G. AITKEN, G. E. HALE, B. BENFIELD, W. W. CAMPBELL, A. L. BLACK, J. H. MOORE, STURLA EINARSSON.

Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
Finance Committee—C. S. CUSHING, W. H. CROCKER, A. H. MARKWART.
Library Committee—D. S. RICHARDSON, F. V. CORNISH, BERNARD BENFIELD.
Comet-Medal Committee—W. W. CAMPBELL, STURLA EINARSSON, H. M. JEFFERS.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 128 Lick Building, 35 Montgomery Street, San Francisco, California. Subscription price, $5.00 per year.

ASTRONOMICAL SOCIETY OF THE PACIFIC

THE ADOLFO STAHL LECTURES IN ASTRONOMY

This volume contains the twelve Adolfo Stahl Lectures which were delivered in San Francisco in the seasons 1916-17 and 1917-18 under the auspices of the Astronomical Society of the Pacific by members of the staffs of the Lick Observatory, the Mount Wilson Solar Observatory, and the Students Observatory at Berkeley. They cover a wide range of topics, the endeavor being to present in non-technical language, but without sensationalism, some of the more recent results of studies of the Sun, the Moon, the Comets, the Solar System in general, the Stars and the Nebulae. One lecture, also, treats of the methods of astronomical discovery; another of recent progress in the study of motions in the solar system; still another, of the important epochs in the development of astronomy; and the volume concludes with a description of the great 100-Inch Reflector on Mount Wilson, the most powerful telescope in the world.

The volume is well illustrated. There are fifty-four full-page plates and twenty-four figures in the text. Altho the illustrations were selected primarily with reference to the text, they include some which are of historic interest and others which present some of the most recent developments of astronomy. For example, we have Keeler's beautiful drawing of Saturn made on January 7, 1888, the night on which the first successful observations were secured with the 36-inch refractor of the Lick Observatory, and the recent photographs of Jupiter, taken by Slipher at the Lowell Observatory, which are the finest ever made. Some of the stellar and nebular photographs, like the excellent one of the Pleiades by Dr. Isaac Roberts, in 1888, represent pioneer work in this field; others, like Barnard's photograph of the Milky Way in Ophiuchus and the photograph of the Great Nebula in Andromeda showing the location of the Novae recently discovered in it at Mount Wilson are typical of the best work with modern telescopes. On one page we find a photograph of the first reflecting telescope, the historic one-inch invented by Sir Isaac Newton; on other pages, views of the 72-inch reflector at Victoria and the 100-inch reflector at Mount Wilson.

It is, of course, impossible to cover the entire field of astronomical research in a series of twelve lectures; but the topics discussed are representative of modern astronomical work, and the book will introduce the reader to the point of view from which the astronomer of today regards the problems presented to him.

PUBLICATIONS

The volume has been printed for the Society at the Stanford University Press and is ready for distribution. The price of the book, substantially bound in cloth, is $2.75, postage paid. Orders should be sent to Mr. D. S. Richardson, 709 Postal Telegraph Building, 22 Battery Street, San Francisco, Cal.

Mr. Stahl has generously provided that the proceeds of the sale of the volume shall go to the Society to form a special fund.

Astronomical Society of the Pacific.

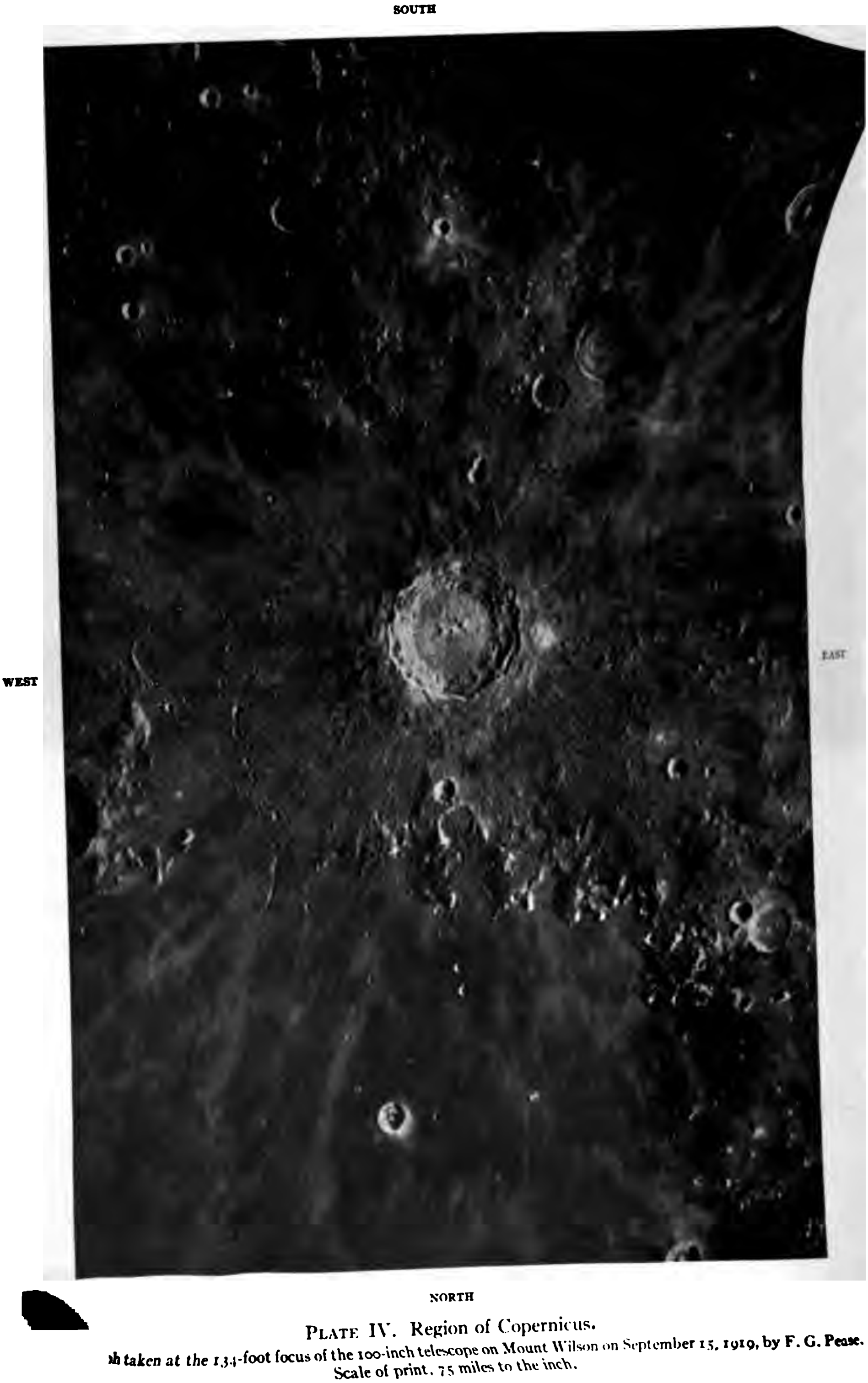

PLATE IV. Region of Copernicus.

h taken at the 134-foot focus of the 100-inch telescope on Mount Wilson on September 15, 1919, by F. G. Pease. Scale of print, 75 miles to the inch.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXXII. San Francisco, California, April, 1920 No. 186

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO ERNEST W. BROWN, PROFESSOR OF MATHEMATICS AT YALE UNIVERSITY.

By Beverly L. Hodghead

The Astronomical Society of the Pacific has now had a successful existence of more than thirty-one years It embraces in its membership most of the astronomers of the Pacific Coast, many in other parts of the world, and many laymen who are keenly interested in the progress of astronomical science. The lay members are of but little service beyond the payment of dues for the upkeep of the Society, but their privileges are many. Aside from the opportunity of pleasant association with the leaders of astronomical thought and discovery which excite a lively interest among many persons who are themselves unacquainted with its more technical and intricate problems, it is to them a school of great value. Climatic conditions in California are favorable to celestial observation. Fortunately, the popular interest aroused by the dissemination of astronomical information has extended to many whose financial substance and generous natures have prompted them to make endowments for the further progress of the Society and advancement of the science. The permanence of the organization is now assured by its large membership, its sound financial condition and its long period of successful existence. Its useful agency is attested by the wide and sustained interest in its proceedings and by the recognized value and high standing of its Publications, which are issued bi-monthly, under the editorial supervision of a publication committee composed of professional astronomers. One of our former presidents, writing recently from Boston, refers in this connection to the estimate of the late Professor E. C. Pickering, who expressed to him the opinion that the Publications of the

Astronomical Society of the Pacific was the best astronomical journal of its kind in existence. This item of self-praise is justified, because a tribute from such eminent authority is deserving of publication, that the Committee may be encouraged by the appreciation which its journal receives. The Committee labors with much professional zeal but without compensation other than the satisfaction of contributing to the advancement of science.

The library of the Society contains in addition to the 31 volumes of its own publications about 6600 books and pamphlets relating to astronomical subjects. Among the most recent additions is the volume which contains the compilation of lectures made possible through the generosity of Mr. Adolfo Stahl, one of the benefactors of the Society. The library is now housed and conveniently indexed and arranged in the Sutro Library in the Stanford University Medical Building, at Webster and Sacramento Streets, San Francisco.

The primary purpose of the meeting tonight is to award the Bruce Medal and to hear the address of Professor Brown, who is to receive it. The meeting is one of the most remarkable in the history of the Society in that it is attended by a larger group of the leading astronomers of the country than has come together here in recent years.

At some risk of repetition, it may be appropriate to explain to the newer members of the Society the history of the Bruce Medal and the manner in which its award from year to year is made. In 1897 Catherine Wolf Bruce endowed the Society with a fund of $2500 to be invested and the interest therefrom used each year for the purchase of a gold medal to be awarded for *distinguished services to astronomy*. The terms of the endowment define the manner in which the award is to be made, which is that the Directors of six of the most prominent observatories in the world—Berlin, Greenwich, Harvard, Lick, Paris and Yerkes, are each invited to nominate three astronomers worthy to receive the medal. From these nominations the award is made by the Directors of the Society. At a meeting of the Directors in March of last year, the observatory of Cordoba, in the Argentine Republic, was substituted for the observatory at Berlin, for reasons which are obvious. The award was suspended during the period of the war, consequently the one given this evening is the fifteenth award to be made.

It is my privilege this evening to announce that the medal for the year just passed, upon the nomination of the six observatories last above referred to and by order of the Directors of the Society, is awarded to Professor Ernest W. Brown of Yale University, and it is no less pleasure to add the announcement that as a result of a very pressing invitation, Professor Brown is with us this evening to receive this medal in person and afford us the pleasure of his acquaintance and to give us an address. It is further in keeping with the custom of my predecessors to follow this announcement with a brief statement of the reasons for the award and a reference to the life of the recipient.

Professor Brown was born at Hull, England, November 29, 1866, and graduated from Christ College, Cambridge, in 1887. He received his master's degree in 1891 and was a fellow in that institution until 1895. From 1891 to and including 1907 he was Professor of Mathematics at Haverford College, Pennsylvania. Since 1907 he has been Professor of Mathematics at Yale University, where the authorities have offered him every facility for the prosecution of his researches and the publication of their results. Professor Brown tells me that his life has been so uneventful that biography is difficult. His story, in brief, is that of a rather delicate youth, carrying on his studies with his father's hearty encouragement and support and emerging, at college, into sturdy manhood with strength for hard study and such vigorous exercise as rowing in the college boats at the races. The record of the years since leaving college is one of quiet study and teaching, with travels in many lands for the necessary recreation.

Astronomy invites specialization, and Professor Brown is a specialist. Like Leuschner, of Berkeley, and Moulton, of Chicago, he has confined his researches almost exclusively to the field of celestial mechanics. Indeed, he has devoted nearly all his spare time for the past thirty years to the single problem of improving our knowledge of the theory of the Moon's motion and of constructing accurate lunar tables. Such work is far less spectacular than the discovery of new planets or other celestial bodies; but that its value is not less to science is attested by the fact that Cambridge University, England, the Paris Academy of Sciences, the Royal Astronomical Society of London, and the Royal Society of London, have anticipated our own action in awarding prizes and medals to Professor Brown for his distinguished services to astronomy.

It was at the suggestion of his friend and teacher, the late Sir George Darwin, that Brown, while still at Cambridge, began to read G. W. Hill's papers on the lunar theory. This was the beginning of a task happily completed in the present month by the publication of the *Tables of the Motion of the Moon*. The whole ambitious plan was not mapped out at the outset; else its stupendous proportions might well have proved discouraging. His program, rather, developed as the work proceeded. Beginning with an extension of Hill's work, Brown was led gradually to a complete development of a lunar theory that includes "the gravitational action of every particle of matter which can have a sensible effect on the Moon's motion, so that any differences which appear between theory and observation may not be set down to want of accuracy in the completeness with which the theory is carried out. Every known force capable of calculation is included."

When this had been accomplished, by 1908, he undertook the further task of putting the theory completely into numerical form and of constructing tables which would enable the computer conveniently, and in a relatively short time, to calculate the Moon's position for any desired date or series of dates.

I myself must not attempt unassisted to describe or review this great work; it is better to be right than to be an author. Therefore, I have requested and received the assistance of a professional astronomer in arranging the following brief general statement of the problem upon which our medalist has been so long engaged and of the significance of his contribution to its solution. My friend agrees with me that a detailed technical review is unnecessary and would, indeed, be out of place on this occasion.

If the Moon's motion were controlled entirely by the mutual attraction between it and our Earth, and both of these bodies were perfect spheres, its orbit would be a Keplerian ellipse and the solution of the problem of predicting the position of the Moon for any desired epoch would be a simple one. This, however, is not the case; the Sun's attraction, first of all, enters as a powerful disturbing force and the Moon's actual motion thus presents a special case of the famous three-body problem, the complete theoretical solution of which transcends the power of our mathematics. Moreover, the attractions of the planets, each in its degree, enter either directly or indirectly, and the departure of the Earth's form from perfect sphericity introduces perturbations that are by no means to be neglected. Further, the Moon is relatively so close to the Earth that very minute discrepancies between the observed and predicted motion are at once revealed. Suppose, for example, that the Moon is but a mile or two ahead of or behind its predicted place; such a discordance would be revealed by modern accurate observations. In the case of a satellite of *Jupiter* a difference of *100 miles* between the true and computed places would produce an angular displacement too small to be detected by our most powerful telescopes.

The result of these conditions is that the problem of the lunar motion is by all odds the most complicated one in the whole range of celestial mechanics. A complete solution, as has been said, is beyond our powers—just as, in a very different way, it is beyond our power to find a number whose square shall be precisely two. But just as we can find a number whose square shall differ from two by as small an amount as we please, so, by throwing the mathematical expressions for the Moon's motion into the form of suitable series and taking account of a sufficient number of terms, we may carry our approximate solution to a degree of completeness that will answer the needs of the most accurate modern observations. The development of the necessary expressions, however, presents a problem lying on "the very frontiers of mathematical astronomy, and one that can be dealt with only by the ablest and most skilful analysts." We may properly take pride in the fact that two of our earlier Bruce Medalists—the late Simon Newcomb and the late G. W. Hill—made distinguished contributions to its solution. Our present medalist modestly said, a half dozen years ago, that his own theory was rather the fulfilment to the utmost of the ideas of others than a new mode of finding the Moon's motion. "Its object was severely practical—to find in the most accurate way and by the shortest path the complete effect of the law of gravitation applied to the Moon." Doubtless this statement is correct; unquestionably, Brown is indebted to Hill just as Hill was indebted to Euler. But this does not in the least detract from the merit of his work nor does it imply in him any lack of originality. Indeed, the methods he has employed in his developments exhibit in the most striking way his mathematical resourcefulness and his originality of mind. It is, however, not in my province to enter upon technical details; let us rather inquire as to the advance in the accuracy of our knowledge of the lunar motions which has resulted from Brown's work.

Here I may to advantage quote the statement of Mr. W. H. Maw, President of the Royal Astronomical Society, in 1907, in awarding the Gold Medal of the Society to Professor Brown. Hansen's *Tables de la Lune*, with one or two corrections supplied by Newcomb, have been used from the date of their publication more than half a century ago up to the present time in most of the national Almanacs; but, says Maw:

> "When Professor Newcomb made his comparison of Hansen and Delaunay, we were in doubt as to the value of some of the coefficients in longitude to the extent of half a second of arc at least; also the motions of the perigee and node were uncertain to correspondingly larger quantities. On the other hand, the degree of accuracy aimed at by our medalist [and, I may interpolate, achieved by him] has been such that there should be included the coefficients of all periodic terms in the longitude, latitude, and parallax which are greater than 0.01 of a second of arc, and that the results should be accurate to this amount."

Now, in one sense, the lunar theory is complete when the analytical expressions showing the action under the law of gravitation of every particle of matter which can have a sensible effect upon the Moon's motion have been worked out. Practically, however, it is also necessary to determine the position, speed and direction of motion of the Moon for some initial date by comparison with actual observations. To secure the required accuracy in the determination of these constants comparison with long series of observations is necessary. At Greenwich the Moon has been observed regularly since 1750, perhaps, on the average, 120 times a year. The resulting 20,000 or more positions, together with shorter series obtained elsewhere, afforded Professor Brown the data he required. It is not implied that he dealt with all these observations from the start. He himself says: "Other workers, notably Airy in the last century and Cowell in this, have done the greater part of the labor. My share was mainly to carry theirs a stage farther by adopting the latest theory and the best modern practice for the reduction of the observations."

Given the theory and these constants expressed in complete numerical form it is only necessary, in order to find the Moon's place at any date, to insert that date and perform the required numerical calculations. But to solve the expressions directly for every desired date would involve a prodigious amount of labor.

Hence the final task was the construction of tables to facilitate the work.

"A table," says Professor Brown, "is mainly a device by which calculations which are continually recurring are performed once for all time, so that those who need to make such calculations can read off the results from the table." The problem was to fit the terms into the smallest possible number of tables and to reduce to a minimum the labor of interpolation between the successive entries in each table. It is, as our medalist says, a problem in combinations, "something like a mixture of a game of chess and a picture puzzle, but unlike the latter in the fact that the intention is to produce ease and simplicity instead of difficulty." Obviously, one man could not, even with the aid of such ingenious devices as the harmonic analyzer invented by Professor Brown, carry out the extensive computations for these tables single-handed. As a matter of fact, our medalist secured the services of Dr. Henry B. Hedrick at the outset, and Dr. Hedrick spent nearly his whole time on the work for nearly nine years, assisted by from one to four computers according to the requirements. Credit is due to Yale University for meeting the cost of these calculations and of the printing and publication of the Tables.

The success achieved may be judged from this statement in the preface to the Tables:

> "We have been able by various devices to include every known sensible term and also many that separately must be classed as insensible in comparison with modern observations, but which in the aggregate will occasionally show themselves. Altho nearly 1500 terms are included—nearly five times as many as are contained in Hansen's Tables—the time needed to obtain the annual ephemeris is certainly not greater than, and is probably less than, that which the use of Hansen's Tables demands." It is also stated that final searching tests applied to the proofs revealed only three cases of wrong terms inserted "and these so small as to be only worth mentioning as a matter of record."

It should be added that the ephemeris computed from Brown's Tables will be inserted for the first time in the national Almanacs for 1923.

I may conclude with the statement that our medalist's work supplies a satisfactory solution of the lunar theory under the law of gravitation, but that it does not finally dispose of the problems raised by the Moon's observed motion. As he himself says:

> "While many efforts have been made in the past to represent the motion of the Moon by gravitational theory alone, it is now admitted that this cannot

be done completely. When we attempt to represent ancient and modern observations by the same set of constants, it is found that, whatever adjustments be made, there is some disagreement with theory. The same is true of the modern observations. There are oscillating differences which do not correspond to any theoretical gravitational terms, and they are large enough to exclude the possibility of being due to errors either in the theory or in the observations."

No satisfactory explanation for these differences has yet been found.

His *Lunar Theory* and *Tables of the Motion of the Moon* constitute our medalist's most extensive piece of work; but it must not be inferred that his services to astronomy are limited to these researches. In point of fact, he has been engaged upon many problems, including librations in planetary systems, and periodic orbits connected with the Trojan Group of minor planets whose mean daily motions in their orbits about the Sun are almost the same as that of *Jupiter*. Time does not permit me to enter upon any details of these researches.

I now take great pleasure, Professor Brown, in presenting to you, on behalf of the Astronomical Society of the Pacific, and in accord with the award of the Board of Directors, the Bruce Gold Medal. We congratulate ourselves that we are able to add your name to the list of illustrious astronomers who have previously received this award.

THE PROBLEM OF THE MOON'S MOTION

By Ernest W. Brown

The beginning of the problem which is known as that of the motion of the Moon about the Earth, or briefly, the lunar theory, goes back to the earliest time in history, when man began consciously to observe nature. The Sun he would easily consider as part of the regular order of things dividing day from night and so much a part of daily life from his infancy as to escape his curiosity. The Moon, however, with its constant changes in appearance and position and yet with a certain degree of regularity would probably be one of the earliest objects of speculation. It formed the first rough measure of the passage of days to a race whose cradle was sufficiently far from regions where the Sun never rises far above the horizon in winter. To this day it is used by uncivilized tribes to measure off periods, rather than the year, which holds too many alternations of light and dark to be counted.

The earliest record we have comes from the clay tablets of the Babylonians. They knew that there existed a cycle of between eighteen and nineteen years—the Saros—in which the eclipses of the Moon repeated themselves. This fact alone shows careful observation and record which must have extended over at least a century and probably very much longer. It is interesting to speculate on various deductions which might be made from this record alone. Clear skies must have been the rule and cloudy nights rather rare exceptions. For the phenomenon had to be seen and noted as something unusual and not to be explained by clouds. And the observers also must have had the opportunity to see plainly most of those eclipses that took place. Again the knowledge gained must have been handed on to the next generation at least and more probably thru several generations in an age when scientific record was the exception, giving the impression that it was cared for by some body of men who formed a school or priesthood. The knowledge may have been used for impressing the populace by predictions of events which would not need to be explained away. But I think that the very nature of the record seems to indicate that it was not kept as a "secret of magic," at least in the later days. The Babylonians were fond of numbers and used them in many ways; they could "write a washing bill in Babylonic Cuneiform."

A gap of two thousand years in our knowledge of the past brings us to Hipparchus, the Greek, who lived near the golden age of that civilization, and later to Ptolemy, who gathered together the work of his immediate predecessors. At this time they had observed enough to become puzzled at the want of regularity in the Moon's motion amongst the stars. It had not the perfection of the circle which the Greeks felt should belong to the motions of the heavenly bodies and the names of some of the deviations from uniform circular motion date from this period. Knowledge grew slowly in the next 1500 years. It was not until the time of Tycho Brahe, the observer who recorded the motions of the planets and Sun and Moon, that the foundations were laid for a more perfect classification of the peculiarities of these motions. Then came Kepler who, abandoning the idea that circles were the only curves which were suitable to represent all the different motions of these bodies, finally after many years of patient work on the observations of Tycho Brahe, hit on the ellipse as the best solution of the problem.

This is the end of the first stage—the observations gathered together, arranged in orderly fashion and so grouped that a simple well-known curve would describe their main features. This was at least true of the motion of the planets round the Sun, once the idea for which Galileo is the historical protagonist had been generally accepted by the scientific men of the time. It was less true of the Moon, which showed deviations which could not be grouped in so simple a manner. Something more was needed not only to explain these, but also to find the reason why all the planets moved in ellipses with the Sun in one focus which was common to all of them. And Kepler had found two other facts which connected their rates of motion, the times in which they described their circuits and their distances from the Sun. The answer was supplied by Isaac Newton, who was able to give a solution—the law of gravitation—which could put in a single statement all the facts which Kepler had brought together and more particularly which showed that the motions of the Moon were no exception.

This second stage reached the heart of the problem. Once the laws which all matter obeys had been fully formulated and tested with such observations as were then available, it was necessary to find out all the consequences of these laws. For this the older methods of mathematics were quite insufficient. It was necessary to find some weapon much more powerful than the simple arithmetic, algebra and geometry which were the chief content of mathematics as taught in Newton's time. Newton and his contemporary Leibnitz furnished this, the one by the invention of the method of fluxions or rates, as we should now call them, and the other by what amounted then to the same thing expressed in a more suggestive notation, the calculus. From that time to the present day the mathematical astronomer with the assistance of his co-operator in the observatory, has been testing the full consequences of the law of gravitation.

Man is so constituted that he never remains long content to have arrived at the source of the power which is responsible for the working of a large and complicated machine. He may be convinced that he has arrived at the place where he can learn all that is to be known, but he will soon try to attain that knowledge. The law of gravitation may be responsible for all the working of the solar system and of the stellar universe, but it is only natural to follow out the various lines which radiate from the central power-house and examine in detail each of them to its furthest extent. He will be on the lookout, too, for indications as to other sources of power. To do this in the case of gravitation means careful exploration of every detail, the more careful the more difficult it appears to be to find other sources. And with this law it is peculiarly necessary. It leaves so few things within its province which cannot be traced back to it that the most thoro investigation is necessary if we are to discover anything new. It is here that the Moon comes to play an important part. It is so near to us and gives so many opportunities for thoro observation that we may hope to find out more from it than from any other single body in the heavens. It is true that it is only one of them but it is that one in which the play of the gravitational forces has the most varied effects. Hence it is not strange that more labor has been devoted to elucidating its motions than those of any other body.

What is it that has to be done? The consequences of the law have to be deduced and to be expressed in a form in which they may be most easily compared with observation. This expresses in a single sentence the work to which several of my predecessors have devoted a large part of their energies. I shall try in as few words as possible to give some idea of what it involves. Only one man can be said to have accomplished the whole of it with any degree of completeness. Hansen, who lived in the first half of the nineteenth century, not only constructed a new method for working out the consequences of the law as applied to the Moon but constructed and calculated tables for simplifying the results so that the labor of finding the position of the Moon at any time should not be too great. Most of the other workers had a less ambitious program or, like Delaunay, died before it was completed. In my own case, there was the foundation of a new method, that given by G. W. Hill, in existence, and the ideas of Hansen and his successors as to how tables should be constructed were available. Of course all the algebraical and numerical calculation had to be done afresh and much greater accuracy and completeness were necessary if the work was to be worth doing at all. Much of it called for careful organization and thoro tests rather than mathematical ability and its completion at the present time is largely due to favorable working conditions and financial assistance forthcoming when it was most needed to provide for the more mechanical parts of the calculations.

What is known as the "theory" consists in constructing a set of differential equations which are the symbolic expression of the laws of motion and the law of gravitation, and then in solving them so as to get the three co-ordinates—the longitude, the latitude and the parallax—expressed in terms of a single variable quantity, the time, so that by substituting any given date in the expressions we may obtain these co-ordinates by straightforward numerical calculation. The problem would be simple enough if a spherical Earth and a spherical Moon were the only bodies to be considered. But the Sun altho so far distant from the Moon compared with the Earth has a much greater mass and its attraction causes considerable deviations from simple elliptic motion. Then the planets *Mercury*, *Venus*, *Mars*, *Jupiter* and *Saturn* all produce sensible effects and we have, too, to take account of the fact that neither the Earth nor the Moon are perfect spheres. The chief difficulty comes from the fact that we can only express the results as sums of many hundreds of terms each of which has portions which come from many different parts of the calculations. I can perhaps best give an idea of the extent by mentioning that the number of figures written mounted to four or five millions not counting algebraic symbols or the figures which pass thru the mind while doing the calculations. This work took nearly 10,000 hours of my own time and that of one computer. In the final results about 1500 terms were left which seemed large enough to be recorded as having an effect to be included when obtaining the position of the Moon at any time. Practically every term is of the form $a \sin (bt + c)$ that is a harmonic function of the time, in which a, b and c have numerial values which differ from term to term.

The results are then ready for the observer whenever he wishes to compare the theoretical position of the Moon with its observed place. But if he had to calculate from these 1500 terms every time an observation was made the work would be so great that few would be found to undertake it. We can easily estimate what he would have to do. He would have to add 1500 numbers together in three groups and I doubt whether he could get any one of them with less than five minutes' work. The whole would take not less than 100 hours of work and would probably demand double that time. The *American Ephemeris* gives the place of the Moon every hour thruout the year. On this plan some thirteen million numbers would have to be added and the time demanded to get the positions of the Moon for a single year would be at least a million hours. It is to abbreviate this work that Tables of the Moon are constructed.

This is done mainly by two principles. First the fact that the motion is continuous and follows a regular law for a short time enables us to perform the calculation once every twelve hours instead of once an hour. This law tells us that even the shortest of the cycles described by the various terms in the motion is much longer than twelve hours and that if we know the place at 12-hour intervals a simple calculation from the places themselves will give the place at every hour: the process is known as interpolation. The amount of labor involved in this process will be easily understood by the astronomer when the fact is mentioned that differences up to the fourth inclusive are used. The number of items is thus reduced to a million or so.

The second principle is to do all the calculation which can serve for any date before applying the results to a given date. This requires a careful examination of the results in order to see what can to done. First the angle under each sine is tabulated so that its values are half a day apart and the sine of each is multiplied by the coefficient. The sine has the property of repeating its values whenever we add 360° to the angle so that all the values of the term which will ever be needed can be obtained from such a table by interpolation; we can of course find as many intermediate values to save the latter process. This reduces the time for the calculation of any term from five minutes to perhaps half a minute: the number of hours required is reduced to ten thousand. Next it is found that many of such tables can be added together so as to form only one table. As a matter of fact the 1500 terms in my theory have been placed in fewer than 150 tables, so that the time required is again divided by ten. Finally the translating of the date into the angle is done by a set of tables and simple rules which save more time. It turns out that the ordinary ephemeris computer should be able to do the whole work on the ephemeris for a year in from six to nine months according to the amount of time he has to spend in checking up his work. The whole idea is similar in principle to that which a factory adopts in sending out its product. It ships in bulk and retains bulk as long as possible, breaking into smaller portions at certain central points, in order to distribute to the dealers who finally get out the single packages for sale to the public. The advantage of this method over that of sending each package direct to the consumer needs no comment. If we try to continue the simile further back, the "theory" will compare with the work done in the factory where the raw material furnished by the laws of motion and gravitation is worked up into the finished product, ready for distribution.

I have not mentioned one feature of the theory which is a very important part of the work. The laws do not give certain constants which can only be found from observation. We must, for example, know the average time of revolution, the mean distance and so on by direct observation of the Moon. The process consists in calculating the position with rough values of these constants and correcting them from the differences between theory and observation. If we had to start at the beginning knowing little about these constants the work would be intensely laborious. But perfection of theory and observation have gone hand in hand and we have now got very accurate values of these constants. But still each time the theory is improved the constants need correction. Hence while the Tables were being calculated, the past observations of the Moon were compared with the new theory. Some 20,000 of the Greenwich observations made in the last 150 years were used since the more observations which could be incorporated, the more accurate would be the averages. My own part in this was not a very serious undertaking for all the really laborious work had been done by my predecessors and this had only to be corrected and discussed afresh. I had the advantage not only of being able to use this work of Airy and Cowell, but also that of Newcomb, who obtained his results from occultations of the stars by the Moon—a quite separate set of observations. The final agreement after the two sets had been corrected and discussed showed that there was little to be desired in the way of accuracy in the constants of the Moon's orbit.

Navigators have almost ceased to use the Moon to obtain their positions at sea, owing to the excellence of modern chronometers and the development of wireless telegraphy, and there are few, if any, other practical needs for accurate observations of the Moon. The objects of this work are therefore chiefly scientific and I shall now try to explain why such a detailed study of the motions of one body of our solar system is worth while. Some mention has been made of the continued interest for itself alone of the workings of the law of gravitation and of the many possibilities which exist in the lunar problem. But at the present time the matter of chief interest is the remainder after the effects of gravitation have all been subtracted. Many of the older sciences have reached the stage in which we can only hope to learn something new by the most careful study and comparison. The lunar theory is more than 230 years old, and during its life has never failed to have many devotees. The last refinements are now necessary. It is for this reason that the attempt was made to leave no gravitational source untouched which could have any effect sensible to observation now and for many years to come. The contest between theory and observation, like that between the shell and armor plate, is continuous. As far as gravitation goes the theory is now in the ascendant and to learn more about the residuals, whose laws of change are as yet uncertain, we need many years of observations as refined as possible.

This seems to be an opportunity to sum up briefly what is now known about the most famous of these residuals. I shall not confuse the question by going into its history. The gradual apparent decrease in the length of the month—usually known as the secular acceleration of the Moon's mean motion can be determined by theory with great exactness. This effect causes the Moon to be ahead of its place six seconds of arc in a century more than if it did not exist. But the effect varies as the square of the time so that 2000 years ago, the accumulated change would be 2400″ or two-thirds of a degree. It will be seen that we can only test it after very long intervals of time. Now an eclipse is a very sensitive test for such a change. Even a third of this amount will shift the line on which the eclipse is visible so far that the Sun may not appear totally eclipsed at all. Now we have records of the occurrence of eclipses going far back and they indicate a greater change than 6″ in a century. Unfortunately these early records are vague both as to place and time and one is sometimes even in doubt as to whether the eclipse took place at all. Nevertheless taken all together, they give a fair probability that the increase is about 8″ instead of 6″ so that about 2″ is unaccounted for by gravitation.

Cowell and Fotheringham in England have gone a step farther. They have shown that there are two accelerations in question and that we cannot treat them as if the Moon alone were concerned. The 2″ already mentioned is observed as a difference between the places of the Sun and Moon. There is another of nearly the same amount remaining between the place of the Sun and that of the node of the Moon's orbit. Fotheringham has brought additional evidence to bear on the latter by working up some ancient records of occultations. We thus have two angles made by three lines to consider.

Before the latter difference was discovered the former was usually attributed to a slowing down of the Earth's rate of rotation by tidal friction which would produce the same apparent effect. This rate of rotation is in fact the astronomer's clock and at present the most accurate method of testing the rate of the clock over long periods of time is by means of the Moon. But this comparison is only useful if we know that one of the two is going perfectly. We could in fact attribute the difference either to a speeding up of the Moon's motion or to a slowing down of the Earth's rotation. The latter has what seemed to be a reasonable explanation in the friction caused by the tides. But the second difference probably cannot be attributed to such a cause and we must either abondon the hypothesis or find some other reason for the second difference. Some light may probably be thrown on the question by calculations as to the amount of this friction which have been made lately but which are not yet in a state to use as an argument. There is, I think, a growing conviction that the Earth's average rate of rotation has not sensibly changed within historic times. Cowell suggested that both differences could be explained by a change in the length of the year, but here we are little better off because we know of no reason why this should alter.

Even more puzzling are the curious semi-regular fluctuations of the Moon from its theoretical position which were first discovered by Simon Newcomb. Some six years ago I discussed these in Australia and showed that the Earth and Mercury exhibited deviations of a similar character tho smaller in amount. A little later Glauert confirmed these results and added *Venus* to the group. Following Larmor he suggested that they might be explained by a fluctuation in the rate of rotation of the Earth. But here again causes requisite to produce the amount required seem to be absent. The irregular character and comparatively great magnitude of these fluctuations suggests that there is some set of forces acting on the bodies of the solar system which are related to the known irregular changes in the condition of the Sun. Hypotheses concerning the magnetic and electrical condition of the Sun, Earth and the other bodies are easy to postulate but difficult to confirm. Nevertheless evidence of some connection between these and the Moon's motion are not altogether lacking. The period of rotation of the Sun's magnetic axes found at Mount Wilson is sufficiently close to that of one of the principal lunar periodic terms known as the evection to suggest a long-period change by the phenomenon known as resonance. Long continued observation will be necessary to enable us to see whether the suggestion is of value. What is already known and being discovered, is, however, a sufficient basis to keep the suggestion in mind.

One naturally asks whether the new theories concerning the ultimate structure and nature of matter can have any bearing on these questions. The new law of gravitation, or perhaps stated more correctly, the correction to the Newtonian law of gravitation suggested by Einstein in connection with his relativity theory, is a natural suggestion. One can say almost at once from the form of the law that it is powerless to explain any of these observations of the Moon. But de Sitter has worked the results out with some care and he finds no effect of this kind. There is a slight effect of another kind, but it is too small to be tested in the present state of the theory and the observations. Indeed of the rather numerous anomalies in the motions of the bodies of the solar system it only accounts for one, namely, the motion of the perihelion of *Mercury*, and the strength of the evidence rests solely on the fact that the numerical result is obtained without the introduction of a new constant. This new theory of Einstein's is perhaps the most remarkable working hypothesis of modern times, the triumph of the mathematician and the despair of the physicist, but one must regard it at present as simply a working hypothesis with only a single positive test yet applied as far as the gravitational part of it is concerned.

Some by-products of the work are worth a notice. One is the rate of change of the angle between the ecliptic and the equator. Newcomb believed that the value he got from the occultations was superior to that which could be obtained from observations of the Sun, and as my value agrees with his and has a smaller probable error, I should be disposed to think that, with the great weight of his authority on such questions, the latest value is probably the most accurate of any so far found. A second is the ellipticity of the Earth's figure. Here there is a small but sensible difference of about one per cent from that obtained by geodetic measures and by pendulum observations of gravity. While there are possibilities that the value obtained from the Moon's motion may be made to agree with that obtained from terrestrial measurements by altering certain other rather doubtful constants, I think that the weight of evidence is against such an explanation.

I have so far not mentioned methods by which the place of the Moon is observed. The method of recording the passage of the Moon across the meridian has been used for many years and furnishes by far the largest number of recorded observations which we possess. Within the past few years Greenwich has also added extra-meridian observations with the alt-azimuth and has also used the crater Mösting A as a fiducial point on the Moon's surface as well as the edge of the limb. Occultations of stars are nearly always recorded and they have the great advantage that the instrumental equipment can be of a much less refined nature than that required for meridian observations. Some ten years ago I discussed the question of new methods, using photography with Professor Pickering, which had the fortunate outcome, a few month's later, of producing positions of the Moon more accurate than any of the past methods[1]. Professor Russell, at Princeton, has superintended the measurement and reduction of all the Harvard plates. The latter is somewhat laborious but the results show a smaller probable error than the Greenwich observations and this probable error is mainly due to inaccuracies in the star-positions of the catalogs. Thus with improvements of the latter we should be able greatly to improve the observations of the Moon. There are, it is true, difficulties connected with the illumination of the limb, but these do not seem to be insuperable. The fact that the probable error depends chiefly on those of the star-positions naturally suggests that the Moon might possibly be used to obtain differences of the right ascension of stars which are too far apart to be measured on a single plate. The theoretical motion of the Moon for a short time is, I believe, sufficiently accurate for this purpose. I may add that the chief object for which the method was suggested, namely, to test for systematic error in the Greenwich observations, was attained; no such error was found.

Thus perfection in knowledge of the Moon's motion leads to applications in several directions. It leads not only to more knowledge of the law of gravitation but furnishes possibilities for use as a clock, for use in comparing positions in the heavens and for use in measurements of the Earth.

The past history of lunar theory has been largely the work of individuals, but in the future it will probably not be so. What we are beginning to recognize more and more is that discovery is becoming less dependent on the work of the individual and passing to that of the group. There will be as great need as ever for the directing hand, but the director becomes less and less the dominating genius. He is rather the dominating personality who can stimulate and inspire those who are working with him, who has the conscious or unconscious knowledge which can cause the ideas which are presented to germinate and grow. There is perhaps no one who can feel the need of the group more keenly than he who has worked on a problem alone for much of his life and who has had little opportunity for intercommunication with the few others in his own line except the meager stimulus afforded by a few printed pages appearing at rare intervals. This group tendency is manifested at the present time in the great industrial laboratories, the great institutions for research, the government bureaus, and the universities, where men and women gather together for a common purpose. They are by no means without flaws; every human institution has many defects where the ambitions of the individual cannot be neglected. We cannot in these days go back to the tenets of the school of Pythagoras in which all discoveries were attributed to the founder and which was probably only prevented from early decline by the oath that none of these were to be communicated to those not members. The evolution—for it is evolution and not revolution—which is taking place will need careful guidance. In astronomy, we in America need to make no apology for what has been done and what is being done. There is no group of scientific character that is so united, whose members are so willing to help each other and all who come for help. But we need to consider the future if the same standards of achievement are to be retained. The next generation will soon have to supply the places of those who now direct the work, and it is necessary to see that they are not only fully equipped, but that they are alive to changes in the methods of conducting research and ready to carry them out. Present achievement brings its own reward but the judgment of prosperity concerning ourselves will be largely based on the work of those who succeed us. We must pass on the torch not only lighted and burning brightly but well supplied with fuel. And for this help is needed from all. Those of you whose other occupations do not permit of the opportunity to engage actively in this work have done much and can do much by your active interest and, when necessary by material assistance. I believe that it is no accident that the Astronomical Society of the Pacific has so large a membership of non-professional astronomers. It records a real desire to know something more of our universe and to receive the stimulus which comes from a growing science. The more widespread such interest becomes, the more broadly will the science grow. The future holds much in store and I believe that as in the past you have sown freely and watered liberally so in the time to come, you will reap the harvest which is continually to be gathered in.

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[1] See the article by Professor Russell on another page of this number.—Editor's note.

THE DETERMINATION OF THE POSITION OF THE MOON BY PHOTOGRAPHY.

By Henry Norris Russell.

The value of meetings of scientific societies in stimulating investigation is not confined to the reading and discussion of papers. Many other schemes, which never appeared on the printed programs, have had their inception on such occasions. For example, at the meeting of the American Philosophical Society, ten years ago, the present writer happened upon the late Professor E. C. Pickering and Professor E. W. Brown, deep in the discussion of some astronomical topic. Joining in the conversation, he found them considering the possibility of determining the Moon's place in the heavens by photography, as a supplement to and control upon meridian observations. Having had some experience in photographic measurements, he suggested a plan of attack. Professor Pickering's response was immediate and highly characteristic. "Will you write me a letter, stating in detail just how you think the photographs should be made? Then, if we make them according to these directions, will you have enough of them measured and reduced to see what are the possibilities of the method?" The offer was accepted on the spot, and thus began an observational campaign which is still in progress, and bids fair to continue for years to come.

The present summary is contributed as an illustration of the advantages of coöperation between institutions—in this case, the three oldest American Universities: Harvard, Yale and Princeton.

The primary obstacle to be overcome was the great difference in brightness between the Moon and the stars which have to be used as points of reference. To get stars enough (at least three within 2°30′ of the Moon) it is necessary to go below the eighth magnitude, and the exposure necessary to get good images is more than a thousand times as long for the stars as for the Moon.

This fundamental problem was solved by Professor Pickering, by the use of an occulting disk, a little larger than the clear aperture of the instrument, and set up several feet in front of it. The shadow of this disk protects the objective from the light of the Moon, while the light of stars which are not too near the Moon's limb can pass by it on one side or another and reach the plate. Good star images can thus be obtained without fogging the plate with diffused moonlight. To get an image of the Moon, the disk can be turned edgewise, allowing the light to pass for a fraction of a second. The times of beginning and ending of this short exposure are recorded automatically on a chronograph.

In this way excellently measurable images of both the stars and the Moon can be secured on the same plate; but another danger is incurred. If the driving clock is not of exemplary behavior, the telescope may be directed toward a slightly different point of the heavens during the short exposure on the Moon, and, on the average, during the long one on the stars. It is therefore necessary to employ an instrument which has a mounting of the highest mechanical excellence.

For this reason the 10-inch Metcalf Telescope of the Harvard College Observatory was used, with aperture reduced to 3.5 inches. The occulting screen was 5 inches in diameter, and carried by a pole nine feet long. With this equipment, the normal exposure of ten minutes gave measurable images of stars between the magnitudes 6 and 8.5. The exposures on the Moon varied from 0.2 to 0.6 seconds, according to the phase, and averaged $0^s.28$—less than 1/2000 of that on the stars. This gave lunar images which were sharp at the edge, but by no means opaque—a great advantage for measurement.

The photographic observations were all made by Professor E. S. King of Harvard, with notable success, very few plates indeed having to be rejected as deficient.

The measurement and reduction of these plates was carried out at the Princeton University Observatory. It can be recommended as an excellent training for students, for it involves the application of all the corrections previously known to astronomical photography, and of a few new ones, invented as the need for them appeared.

The measurement is simple enough. Three or four reference stars are chosen, which must have accurately known positions, and should lie within 2° from the Moon if possible, and form a triangle or quadrilateral enclosing it. It was usually possible to find three stars satisfying these conditions in the recent zodiacal catalogs (Lick, Edinburgh and Cape). If not, the A. G. catalogs were used, and a fourth star added. A réseau of 5^{mm} squares was impressed photographically on each plate before development, and formed a permanent system of reference, to which the rectangular coördinates of the star images could be referred. Eight or ten points on the Moon's limb were also measured on each plate—taking care to keep to the fully illuminated portion, which sometimes demanded a rough calculation if the Moon was nearly full.

In reducing the measures, the first step was to find the Moon's center. This was done by fitting a circle to the measured points on the limb by least-squares, and taking its center as that of the Moon. Before carrying out this process, the measures had to be corrected for the influence of refraction, which distorts the outline of a circular disk into an ellipse with its shortest axis vertical. This effect, which is so conspicuous for the setting sun, amounts at high altitudes to but a fraction of a second of arc, but ignoring it would have resulted in the introduction of systematic error.

The chief source of error in this process arises from the irregularities of the Moon's limb—mountains and valleys seen in profile—which are much larger than the errors of measurement of the photographs. Tho the accuracy of the determination of the center is considerably reduced by these irregularities, the photographic method has here a decided advantage, for the concluded center depends on many points of the limb, and conspicuous elevations or depressions can be avoided during measurement, or given reduced weight in the solutions, while in meridian observations certain definite points of the limb (preceding, following, north or south) have necessarily to be observed, and the influence of elevations or depressions at these points comes in to its full magnitude. For example, a certain region of depression, fully $2''$ below the normal level, showed up so often in our measures that we came to speak colloquially of "falling into the hole" whenever we came upon it anew. This region was directly visible on the photographs as a flattening of the limb, and was so situated that the point observed during transit observations would often fall in the deepest part of it, producing an error of $2''$ in the Moon's observed longitude.

The effects of these irregularities can be very largely eliminated by the application of the "limb corrections" determined by Dr. Hayn. Thirty-eight plates were reduced anew, applying these corrections. The resulting changes in the final positions of the Moon averaged only $\pm 0^{s}.015$ and $\pm 0''.17$ (without regard to sign) and were so small that it did not seem worth while to go to the labor of applying similar corrections to the remaining plates. The observational data have, however, been published in such a form that any one who chooses may work out these corrections for himself.

Another advantage of the photographic method, closely related to the last, is that the Moon's semidiameter can be determined from the plates themselves. It was found that this varied with the photographic density of the Moon's image and increased by about 1".3 from the thinnest to the densest images (after allowing for the variations in the apparent semidiameter due to changes in the distance). By estimating the density of the images by comparison with a standard scale, and taking means, a table of corrections for photographic irradiation, depending on the density of the image, and applicable to the semidiameters interpolated from the American Ephemeris, and corrected for augmentation, was constructed. These corrections were negative except for the densest images, showing that the photographic irradiation was less than the assumed visual irradiation of 1".5, which has been applied in computing the semidiameters in the Ephemeris. It was found that the introduction of these mean corrections gave considerably better results than the attempt to determine the Moon's radius separately from each plate.

In June, 1913, the objective of the Metcalf Telescope was refigured, shortening the focal length by about five per cent, and greatly improving the color correction. Tho this change produced no sensible effect on the appearance of the images, it altered the corrections for irradiation greatly, making them slightly smaller for the dense images than for the thinner ones. New values of the corrections were therefore determined, and the calculated positions of the Moon were corrected to correspond to these.

It is probable that the semidiameter observed visually is subject to corrections for irradiation which are as large as in the case of the photographs, and may be as variable; but no equally satisfactory method of correcting for such variations seems to be known.

Once the Moon's center has been found, the right ascension and declination are determined substantially as in the case of an asteroid. Standard coördinates of the stars are computed from their catalogued positions, and plate constants determined which enable the measured coördinates on the plate to be turned back into right ascension and declination. The resulting positions are mean places, and have to be brought up to apparent place in the usual way, and corrected rigorously for parallax, before they are compared with the Ephemeris. Most of the correction for refraction is made automatically in the determination of the plate-constants; but a small correction for second-order terms remains, which was fortunately easy to handle.

After the instrumental change in 1913, the plates which had previously been exposed flat, were curved to correspond with the focal surface of the objective, in the manner devised by Professor Pickering. This change compelled the application of still another correction to the calculated positions of the reference stars on the plate. The resulting alterations in the computed position of the Moon averaged 0″.4 in each coördinate.

The complete measurement and reduction of one plate forms a good day's work for a practiced computer.

The measures of the reference stars showed that the combined influence of the errors of the photographic positions and the star catalogs, and of unknown proper motions in the ten or twelve years interval between the epochs of the two, corresponded to a probable error of ±0″.57 in either coördinate. Known proper motions were of course applied. One of 0″.7 per year came up on one of the very first plates to be measured—and only one other as large on the next five hundred plates. After correction of the plate-constants for refraction, it appeared that the two sets of réseau lines were very nearly perpendicular—the angle between them differing from 90° by only 1″.9 ± 1″.2, but that the scale values along the two axes differed by 8 parts in 100,000. When the alterations were made in 1913, the plate holder was shifted so that the long axis of the plates ran east and west, instead of north and south. The effect just described thereupon changed sign, proving that it was due to an error of the réseau, and not to optical distortion of the field. The latter must be very small, not exceeding one part in sixty thousand.

The accuracy of the final results is best measured by the agreement of pairs of plates taken on the same night. From 450 plates the probable error of one determination of the Moon's R. A. comes out $\pm 0^{s}.049$ (corresponding to ±0″.68 at the mean declination), and that of an observed declination ±0″.68. The errors of measurement of the photographs contribute relatively little to this—the principal components arising from the irregularities of the Moon's limb, and the abnormalities of the driving clock, and of refraction, at the moment of exposure on the Moon. The smallness of the errors of the last named type was tested, at the very beginning of the campaign, by measuring plates of bright stars, exposed with the occulting screen in the same fashion as the Moon. The final positions of the Moon are nearly equal in precision to the best meridian observations, and have the great advantage that their systematic errors are likely to be entirely different.

The observational errors can not be determined by comparing observations made on different nights, because (as is well known) the errors of Hansen's lunar tables, on which the places given in the Ephemeris are still based, are now large, and vary by several seconds of arc during a month, owing to errors and incompleteness in the periodic terms in longitude. The errors in latitude are comparatively small. The resulting errors in right ascension are always positive, and ranged from $0^s.5$ to $1^s.3$ during the period covered by the observations. The errors in declination run up to $6''$, and are positive when the Moon is coming north, but negative when it is going south.

Up to the present time 588 plates have been measured and reduced at Princeton. The results for 11 of these are printed in the *Harvard Annals*, Vol. 72, No. 1; for 204 more, in *H. A.* 76, No. 7; for 273 others, in *H. A.* 80, No. 11; while those for 100 more are in press, completing a continuous record of the errors of the lunar tables from the latter part of 1910 to the end of 1917. The preliminary work on the eleven plates was done by Dr. A. H. Joy and the writer; all the rest have been handled by Miss Fowler, Miss Borton and Miss Fuller, computers at the Observatory. Funds for the prosecution of the work were provided by the Elizabeth Thompson Science Fund, from the Lunar Tables Fund of Yale University, thru Professor Brown, and by a gift to the Princeton University Observatory by the late Mr. A. D. Russell, a Trustee of the University.

The resulting corrections to the Moon's tabular place were communicated to Professor Brown, who made use of them, along with the Greenwich meridian observations, in investigating the errors of the tables. The two series of observations confirm one another completely with regard to the character and amount of these errors. This agreement in view of the radical difference of the two methods of observation, indicates that both are very nearly free from systematic error—a highly satisfactory conclusion.

Work upon these plates at Princeton was interrupted early in 1918 by the diversion of the whole energy of the Observatory staff into war activities. The taking of plates at Harvard has been continued, and it is hoped to resume measurement in a short time.

In view of the irregular, and so far inexplicable, deviations of the Moon's observed motion from gravitational theory, it will probably be worth while to continue the observations for an indefinite period, both to keep track of the fluctuations of long period, and to determine whether these are accompanied by short period displacements not accounted for by theory.

Another possible application of the method, suggested by Professor Brown, is the making of simultaneous observations at stations in the northern and southern hemispheres. One naturally thinks that the object of such observations would be to determine the lunar parallax; but it turns out that the distance of the Moon can be calculated more accurately from its period (cleared of perturbations) and the force of gravity at the Earth's surface than it can be found by direct observation. Hence the observations can best be used to get the distance between the two terrestrial stations—that is, to find the ellipticity of the Earth.

A variant on this scheme would be to set up one of the observing stations on some oceanic island, such as Hawaii, and the other in the United States. The distance between the two places can of course be computed from their observed latitudes and longitudes, but for an isolated station the latter are affected by "station errors" due to local attraction of the plumb-line, which might be serious on an island rising out of deep water, and could not be determined, as in the case of land stations, by geodetic connection with other places. In such a case it might actually be worth while to impress the Moon into geodetic service as the third vertex of a triangle. By taking two or three hundred plates at each station, the angle at the Moon could be determined with a probable error of about $\pm 0''.05$. This would be equivalent to determining the geocentric angle between the stations with a probable error of $\pm 3''$. Station errors in mountainous countries are often much greater than this.

Princeton University Observatory,
March 1, 1920.

LUNAR PHOTOGRAPHY WITH THE HOOKER TELESCOPE.

By George E. Hale.

My justification for contributing to this symposium is certainly not that of special knowledge. I cannot pretend to have made any serious study of the Moon, and therefore my comments on lunar research are entitled to but little weight. But I could not forego the privilege of joining in this tribute of admiration and respect for the work of my friend Professor Brown, whose fundamental investigations on the motion of the Moon have so richly deserved the award of the Bruce Medal.

The photographs of the Moon reproduced in Plates IV and V have been obtained in the course of a wide variety of tests to which the 100-inch Hooker telescope is being subjected. They are enlarged from negatives made by Mr. Francis G. Pease at the Cassegrain focus of the telescope, where the equivalent focal length is 134 feet, corresponding to a diameter of 15.13 inches of the lunar image (September 15, 1919). Seed 23 plates were used, and the exposures were about one-half second at the terminator, reduced to a smaller fraction toward the much brighter limb by the exposing shutter moved before the plate. The seeing on the night of September 15, 1919, when the photographs here reproduced were made, was hardly better than 3 on a scale of 10. The negatives are sharp, but still sharper ones could undoubtedly be obtained under more favorable conditions. The heavy demands of our regular program of research, however, will leave few opportunities for lunar photography, and these may not often fall on nights combining favorable phase and position of the Moon with the excellent seeing required. Thus it is unlikely that our small collection of good lunar negatives will be rapidly increased.

Our policy will depend, however, upon the possibilities of progress which such photographs may indicate to qualified judges. Few astronomers can claim to possess that intimate acquaintance with the structure and origin of the Earth's face needed in the interpretation of lunar formations At the suggestion of Dr. John C. Merriam a National Research Council committee of geologists, combining the extensive knowledge of topography, volcanology, and other aspects of the science bearing upon this question, will be invited to examine these and other lunar photographs, and to co-operate with the Mount Wilson Observatory in a study of the Moon if this should appear sufficiently promising.

It is clear that no such study should be based upon photographs alone, as these do not reveal the smallest details visible at the telescope. I have examined the Moon with refractors and reflectors ranging in aperture from 3 to 100 inches, and have been greatly impressed by the exquisite structure, of the most minute pattern, seen with large instruments under the finest conditions. One of the most striking features of this structure results from the presence of innumerable small holes or "craters," similar to those shown in the photographs, but much smaller in diameter. These minute objects, resembling the smallest needle pricks, are particularly numerous on the outer slopes of the walls of Copernicus, where they present a remarkable spectacle. In 1894, when I spent a week with the late Professor Riccó at the summit of Mount Etna, I was struck with the appearance of the many small craters, some still smoking, others dating from prehistoric times, that dotted the slopes of the volcano. Whether these have more than a superficial resemblance to the minute holes seen on the walls of Copernicus and elsewhere on the Moon is an interesting question.

Adequate explanation of these and other remarkable lunar phenomena will certainly demand extensive research. While one is struck by many resemblances between lunar and terrestrial topography the points of difference are no less striking. The curved chain of the Apennines (Plate IV), about 640 miles in length, rising abruptly from the plain on one side and sloping gradually away on the other, recalls the similar structure of the Rocky Mountains and their precipitous descent into the Nevada desert. Huyghens, the highest peak in the range, reaches an elevation of nearly 20,000 feet. The crater Eratosthenes, lying near the eastern extremity of the Apennines, is about thirty-seven miles in diameter, and contains a marked central peak. The eastern wall rises to a height of some 16,000 feet, while the western wall is only two-thirds as high. The floor of the Sinus Estuum to the south and west, said by Webb to show visually two minute craters with a five and a half inch telescope, is marked on our negatives by many much smaller craters, which are also numerous on the slopes of Eratosthenes.

North of the Apennines, bordering the vast smooth area of the Mare Imbrium, is a group comprising three of the most striking craters on the Moon. The northernmost of these, Aristillus, about thirty-five miles in diameter, has been extensively studied by Professor W. H. Pickering. The double "canal" within its western wall, which he considers beyond the reach of large apertures, is easily resolved visually with the Hooker telescope. Indeed it seems possible that its components might be photographed under the best conditions.

The great crater or walled plain, Archimedes, finds no counterpart in magnitude among the most extensive volcanic phenomena of the Earth. Its diameter of fifty miles greatly surpasses that of the crater of Haleakala (Hawaiian Islands), which is only about thirty miles in circumference, but there are important points of resemblance between the two objects. In fact, altho many lunar craters are depressions below the surrounding country, rather than hollows on the tops of mountains, and altho traces of lava streams, so characteristic of our volcanoes, are usually lacking on the Moon, it nevertheless seems to one who has considered the subject only superficially that the present photographs favor the view that the lunar craters are more probably due to volcanic or other internal phenomena than to the fall of meteorites. The fact that minute craters are much more numerous on the slopes and in the vicinity of large craters than in open plains like the Mare Imbrium, and the almost complete absence of evidence indicating impact at angles differing greatly from ninety degrees, are points to be remembered in this connection.

Copernicus, fifty-five miles in diameter, is one of the finest craters on the Moon (Plate V). Seen under a high Sun, as in this photograph, the shadows of its walls and central mountain are not conspicuous, but the inner terraces and the remarkable system of white streaks, centering in the crater, and extending in all directions to great distances, are brought out to the best advantage. The origin of these radial bands, and of the longer ones that center in Tycho, is not easily explained. The enormous number of very minute craters, seen visually with the Hooker telescope on the slopes of Copernicus, has already been mentioned, but attention should be called to the large number of small craters shown in Plate V in the curious region northwest of the great

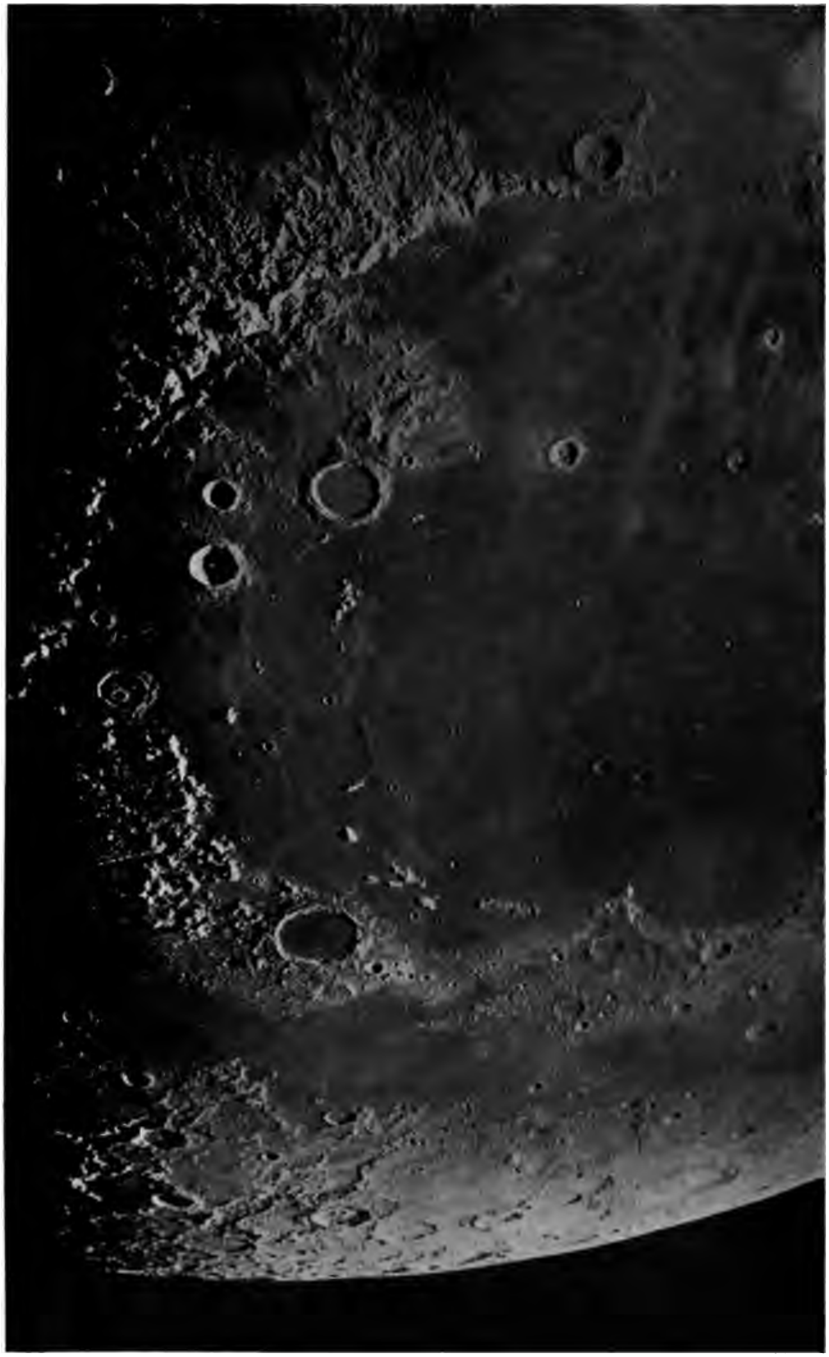

Plate V. Region of Mare Imbrium.
Photograph taken at the 134-foot focus of the 100-inch telescope on Mount Wilson on September 15, 1919, by F. G. Pease.
Scale of print, 140 miles to the inch.

crater. This group, one of the strangest of lunar phenomena, will bear careful study.

It goes without saying that any general attack on selenographical problems should take advantage of all effective observational methods and appliances. Visual observations and direct photography should be supplemented by photography with infra-red and ultra-violet light, and polarization tests should be utilized in promising regions. By these and other means it seems probable that competent observers could add materially to our knowledge of the Moon.

Mount Wilson Observatory
February, 1920

THE ORIGIN OF THE LUNAR FORMATIONS

By William H. Pickering.

Owing to the great number of craters scattered over the surface, the brighter portions of the Moon present a strikingly different appearance from the terrestrial landscape, and various theories have been offered to account for this fact. The darker regions, on the other hand, which form about one-half of the total visible surface, differ much less from the terrestrial continental areas.

The larger lunar craters may be divided into two classes, those with smooth floors like Plato and Ptolemaus, and those with rough and irregular ones like Copernicus and Tycho. This difference is well illustrated in a photograph taken at the Mount Wilson Observatory and published in *Popular Astronomy* for December. The craters Stöfler and Albategnius, altho near the terminator, are seen to have perfectly smooth floors, while those of Tycho and Alphonsus are rough. In the case of the former class the floors are frequently dark like the *maria*, in the case of the latter they are bright and often furnished with a central peak. It is only reasonable to believe that these two classes were formed in the same way, and that the floors of all were originally rough and of the same color as their walls. The modification which subsequently produced the smooth floors appears to have been a welling up of dark colored lava from beneath, like that which produced the *maria*. This lava melted the original floor and central cone, and combined with them. In some regions, such as the western portions of Imbrium and Serenitatis, and the south of Nectaris and Procellarum, the crater rims themselves were partially dissolved in the melted surface of the *mare*. It is clear from this fact that a very large proportion of the lunar surface was at one time or another liquid.

What appears to have happened is this. When the Moon first began to cool, the material of lighter color and lighter specific gravity solidified on the surface. A thin surface shell favors large craters, but there is no evidence that any of these were of an explosive character. When the shell became thicker, and communication with the hot interior more difficult, the craters formed became smaller, and impinged on the larger earlier ones. When the shell contracted by cooling and solidification, the hot molten interior broke thru the surface, in much the same way as now happens on a small scale in Kilauea, Hawaii.

The various *maria* were formed at this period, and about half of the original crust was thus destroyed and dissolved. Had the Moon been much smaller, its surface area would have been larger in proportion to its fluid contents, and a smaller fraction of the surface, or perhaps none at all, would have been destroyed. On the other hand, had the Moon been much larger, the whole of its original surface might have vanished, piece by piece. This is probably what actually happened in the case of the Earth—our larger early craters have all been dissolved one after another, as the result of successive contractions and eruptions, in the igneous rock with which the whole surface was formerly covered.

Our terrestrial craters must therefore be compared, not with the great craters of the white areas of the primitive lunar surface, but rather with the smaller dark ones of the lunar *maria*. Much the largest of these dark craters is Marius, 27 miles in diameter, and situated on the Oceanus Procellarum. The next largest is Reiner, 21 miles in diameter, and located near it. Perhaps the size of the *mare* affects the size of the crater, for those that are next largest are well scattered over the lunar surface. Half a dozen of them, such as Arago, Lambert, Ross, Deslisle and Torricelli, range from 18 to 15 miles, and from that they go down, increasing rapidly in numbers, to the smallest size visible. The three largest terrestrial craters, according to Gilbert, are located in the Philippines, in Japan, and in Kamchatka, and their diameters each measure about 15 miles. Indeed in northern Japan there is a deep circular bay some thirty-five miles in diameter, surrounded by volcanic peaks, two of which are still active. It is known as Volcano Bay, and is clearly an extinct crater, perhaps the largest in the world. It clearly resembles Fracastorius on the Moon. Since our largest craters were necessarily among our earliest, many of them must have succumbed to long continued erosion, and other atmospheric influences, which would not have affected the lunar ones. It therefore appears that the really comparable terrestrial and lunar craters are all of about the same size.

If we compare the lunar *maria* with the similar, somewhat elliptical terrestrial volcanic areas, such as the Caribbean Sea, or the five great seas that bound the coast of Asia on the east, extending from Behring's Strait to the Strait of Malacca, we cannot but be struck with the very small comparative size of the lunar formations. Thus the smallest of these six terrestrial seas, that of Japan, is of practically the same size as the Mare Imbrium.

It is frequently suggested that the lunar *maria* were formerly covered with water, in fact are old sea bottoms. There is no adequate evidence in favor of this suggestion to be found upon the Moon at the present time; in fact all the evidence available is directly against it. The lunar atmosphere, on account of the gravitative constant, can never have been very dense like our own, and the rapid evaporation from extensive lunar oceans under low pressure, and exposed to the tropical rays of the Sun, would have produced deeply eroded valleys and extensive river systems, which are conspicuous on the Moon only by their absence. It is true that very small eroded valleys do exist, also small river beds, the largest of the latter, measuring around the curves, being some sixty-five miles in length. The tapering forms of these last, however, show that their source was in each case a small craterlet in which they terminate, and that the water continuously evaporated as it flowed from it to the lower levels. There is no evidence of great river basins such as are found upon our Earth.

Moreover, the *maria*, altho frequently in communication, are often situated at different levels, as can be seen under a low Sun. Their centers are also higher than their edges. As the water gradually dried up, and the upper areas emptied into the lower ones, distinct channels should have been cut connecting them. Nothing of this sort is to be found upon the Moon, and the *maria* when well seen present precisely the appearance of gigantic lava fields with occasionally wrinkled surfaces, such as must formerly have existed upon the Earth in India and Idaho, and are now seen on a small scale in many terrestrial craters. In order to form a scale of comparison, it may be stated that the lava fields of India are about equal in area to the maria Serenitatis and Tranquillitatis combined.

No evidence of explosive volcanic action of the Vesuvian type has been found anywhere upon the Moon, with the possible exception of the construction of the central peaks of some of the older formations. Vesuvius is itself a central peak, of the extinct Monte Somma. Teneriffe is similar. In both these cases the central peak is much more prominent than the original crater.

On the other hand, in the case of Pico in the Azores, rising to an altitude of 7600 feet, the peak is comparatively insignificant. It rises to an elevation of only 350 feet above the crater floor at its base. The diameter of this outer crater is about one-third of a mile, and thirty feet below the summit of the steep central cone, a little craterlet some fifty feet in diameter was found, still exhaling steam in the summer of 1907. The temperature within the vent was 147°F.

Across the crater floor from the peak to the edge extends a volcanic crack or rill, much like that to be seen in Petavius. Half a dozen little irregular craterlets are scattered along its length, the largest being about thirty feet in diameter. In the earlier days of its eruption the crater was evidently of the explosive type, as is indicated by the loose scoria scattered about its base, but the floor of the crater is solid lava, showing that in its later eruptions it more closely resembled the lunar volcanoes. In the volcanoes of Hawaii, which also resemble those of the Moon, central peaks rarely if ever occur, but little craterlets scattered irregularly over the crater floors are a common occurrence. Indeed, nearly all of the characteristic lunar features are to be found in one or the other of these two groups of islands. (See *Appalachia*, **11**, 344, 1908, *Memoirs American Academy*, **13**, 151, 1906.)

On the other hand, lunar volcanoes distinctly resembling terrestrial ones have also been found. There is one lying between Kies and Mercator whose cone measures 2000 feet in altitude and nine miles across at the base. The summit crater is about 4000 feet in diameter. The mean angle of the outer slope is 4°.8. It is even flatter, therefore, than Mauna Loa, whose slope measures 5°.1. It is illustrated in Figure 6 of the above mentioned *Memoirs*. Many other similar volcanic cones, scattered over the lunar surface, are now known. One with a crater 9,000 feet in diameter lies on a long ridge 130 miles east of Lalande, still another south of Mairan, and another south of Herodotus, and eight between Copernicus and Kepler. A group is suspected northwest of Marius.

At different times various curious theories have been suggested to explain the lunar craters, the chief stumbling block in the way of the volcanic theory, apparently, to their authors, being the great size of the lunar craters as compared with that in Vesuvius. Most of these theories were promulgated before the larger craters about the Pacific were generally known. An early idea was that the lunar craters were the scars left by gigantic bubbles. In volcanic regions where the lava is very viscous, great bubbles several feet in diameter are sometimes formed. The writer, accompanied by several friends, has been inside of such a bubble, left on the lava fields of Arizona. Bubbles one hundred miles in diameter, however, do not seem likely to have occurred, even on the Moon.

Another theory advocated many years ago by Mr. S. E. Peal was that the site of each crater was formerly occupied by a pool of water. As the water evaporated it was deposited as snow in the region immediately surrounding it, thus building up the crater walls. Since the craters must be very ancient, however, their walls in that case would long ago have flattened out in the process of melting and of glacial flow.

Still a third theory, which has recently been revived from obscurity by the great war was first proposed by Proctor in 1873, "The Moon," p. 346. This suggests that the lunar craters are the holes left by great meteors that fell into them in past ages. A crater probably formed in this manner actually exists upon the Earth in Arizona, and possibly a second smaller one has been found. But why there are not more of them, or at least some evidence of their remains, since the Earth is so much more massive than the Moon, has not been explained. It will be noted that the Arizona crater has no central peak. The most popular idea among the adherents of this theory is that these gigantic meteors were revolving around the Sun with planetary speed, but have since disappeared. To this suggestion is raised objection (*a*) that the lunar craters are nearly circular, whereas on the meteoric theory they should in the great majority of cases be ellipses with a marked east and west elongation. To meet this objection it was proposed that the meteors revolved not about the Sun, but about the Earth in a ring, and simply dropped into the Moon by their own gravity, since their orbital speed would be nearly the same as that of the Moon.

To this has been raised objection (*b*) that with only two insignificant exceptions out of several hundreds of cases, among all the lunar craters, the smaller craters impinge on the larger, as they should do if they were of volcanic origin, whereas if caused by meteors, a large proportion of the smaller meteors would fall early, and their craters would be impinged on by larger ones.

Shell craters formed by exploding projectiles were a universal feature of the late war. Smaller craters, but more nearly analogous to the lunar ones, have been formed artificially by drops of water falling on a layer of thin mud, by firing pistol bullets into hardening plaster of paris, and by projecting clay balls against a soft clay surface. By these means even the central peak is occasionally produced by the reaction from the elevation of the crater walls. It is very doubtful, however, if this would occur in a larger formation, and, as we have seen, there is no evidence of it in the case of the Arizona crater.

Craters formed by the projection of clay balls, by solidifying paraffin, where the lower liquid layers are caused alternately to rise and fall as by tidal action, thru holes in the upper solid crust, and a crater formed by natural processes in iron slag are all illustrated in the writer's book "The Moon," Plate A. In the craters produced by projectiles it will be noticed that the outer walls are steep or perpendicular, while the inner walls are shelving. This is the reverse of what we find on the Moon, and may be called objection (*c*). In the craters formed by solidfying paraffin and slag, on the contrary, the inner walls are steep and the outer ones shelving, as on the Moon.

Objection (*d*) to the projectile theory lies in the difficulty of explaining the terraced interior walls of some of the craters, such as Tycho and Moretus, excellent photographs of which by Pease were published in the December number of this periodical.[1] Tidal action on a liquid floor, which solidified before the central peak was formed, would produce just such an effect. The crater Wargentin, in which the sublunar vent became plugged while the floor was at high tide, filling the crater walls to the brim, is a striking example of a phenomenon that may easily be explained by combined tidal and volcanic action, but is very difficult to explain as being caused by a projectile. Wargentin is fifty-four miles in diameter, and rises 1500 feet above the outer plain. It was generally supposed to be unique upon the Moon, but a similar much lower crater, fifteen miles in diameter, lying two diameters southwest of Bullialdus was discovered some years ago, and is described on page 161, and represented in Figure 32, in the *Memoirs of the American Academy* above mentioned.

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[1] It is be to noted that both of these photographs are turned right for left, having been taken with a reflector, and not having been reversed in the enlargement. In the first, the lettering of the orientation is wrong, and an E should be substituted for the W.

A final objection (*e*) may be made to the projectile theory, in that it does not explain the fact that many of the central peaks of the larger craters exhibit small craterlets on their very summits. The exact centering of these craterlets cannot be the result of accident, and while most of them are small like Vesuvius, yet some are large enough to be readily seen in northern climates, even with small apertures. This is precisely the phenomenon we should expect to find if the craters were due to volcanic action. During the past two or three months an occasional search has been made for such summit craterlets, and as a result Table I has been prepared. It is clear from this that but few of the craterlets are larger than that in Vesuvius. The successive columns give the name of the crater, the diameter of the craterlet in feet, the colongitude at which it may be observed to advantage, and the type of central peak on which it is found. The diameters were determined by means of a Scale of Lakes attached to the telescope, such as is used for measuring the size of the lakes on *Mars*, and is described in full in the Report on Mars No. 7, *Popular Astronomy*, **22**, 617, 1914.

TABLE I

Name	Diam.	Colong	Type	Name	Diam.	Colong	Type
Timocharis	11,500	40°	*a*	Albategnius	3,500	20°	*c*
Plinius	9,500	0°	*a*	Alpetragius	3,500	30°	*a*
Herschel	9,500	30°	*b*	Pitatus	3,500	40°	*a*
Landsberg	6,000	50°	*c*	Piccolomini	3,000	350°	*d*
Capella	5,000	350°	*a*	Arzachel	3,000	30°	*b*
Burg	4,000	0°	*b*	Kant	2,500	0°	*b*

The central peaks have been divided into five classes according to the amount of erosion that they exhibit. Those showing little or none, like Alpetragius are classed as *a*. Those where the destruction exceeds one-half the volume of the original cone, and where it is therefore divided into several separate peaks, as in Copernicus, are classed under *e*. (*Popular Astronomy*, **24**, 441, 1916). Where the destruction is great, it will be seen by the table that the summit craters are not generally visible.

In some cases, however, where no crater has been found, even after careful search, we still find evidence of its existence. Thus in the case of Theophilus, whose central cone is deeply eroded, and is in class *d*, we find that the highest of the peaks is only moderately bright, 8, at sunrise, and all the others dark. As the lunar day progresses the peak brightens, and one terrestrial day before lunar noon a minute brilliant point about half a mile in diameter appears on its highest summit. In the next four days four other brilliant points appear on lower summits. After three or four days they all fade away, and before lunar sunset only a few light hazy areas remain. The succession of phenomena is not always identical at different lunations. (*Popular Astronomy*, **25**, 149, 1917.) We can hardly doubt that we have here the clue to the erosion of the central peaks, and that the brilliant points shown indicate the location of invisible craterlets, emitting not ashes or lava, but steam, which immediately condenses to cloud and snow. The deep U-shaped ravines cut in these peaks indicate that in former times the amount of moisture was far greater than at present.

In the case of Kant, included in Table I, the central peak is first clearly seen at co-longitude 347°. It is then sharply defined, and remains so until 20°, but by 35° is distinctly hazy as compared with detail on the crater floor, and the eastern rim. The western rim contains two minute craterlets, and like the peak is now also hazy. This rim and the peak both brighten as lunar noon approaches, the latter reaching 9 and the former 8. By 128° all haziness has vanished, and the craterlet on the central peak appears distinctly surrounded by snow. To detect this the quality of the seeing should be at least 9 on the Standard Scale. The observation was made with an 11-inch aperture and a magnification of 430. It should be noted that a lunar eruption lasting for eight terrestrial days is exceptionally long. Two or three days is the usual limit.

We may indeed say that the arguments of greatest consequence, in favor of meteoric action upon the Moon, lie not in the craters at all, which are generally circular or polygonal, excepting at the two poles, where they have a tendency to be square, but rather in certain long and straight valleys, some of which are fairly conspicuous upon the lunar surface. This view has recently been argued and supported at some length in the *Journal of the British Astronomical Association*, by several writers. Even here, however, the evidence under favorable definition is distinctly against a meteoric origin. The largest of these valleys, located near Rheita, is composed of eight craters in its broader portion, and five where it is more narrow. They are in close contact, and have evidently been exposed to pressure and torsion while in a heated condition, so that they appear a little like a short section of rope.

More than a dozen valleys of various lengths and breadths, and all nearly parallel, are located in the bright portion of the Moon near the center of the disk. The most western of these, some six diameters south of Menelaus is obviously composed of six craters in line, the southern ones being not so clearly marked as those at the northern end. The ruins of transverse crater walls crossing the valleys are seen in some cases. In others the grooves are partly filled with lava, formerly melted, thus concealing their floors and their origin. In the case of Hipparchus there are three short grooves nearly in line, two on the rim, and one between them on the floor. The northern one is the wider, but this is the only case where there is any appearance of the grooves cutting the ridges and skipping the hollows, such as a swiftly moving meteor might do. Immediately west of Albategnius is a longer groove which clearly follows the surface up and down hill. In no case is there any evidence of a meteoric body at the end of the groove. The sides of these grooves are elevated like crater walls, and are sometimes sinuous where different craters have joined one another.

Two and five diameters west of Apianus are two small grooved valleys, composed respectively of five and seven craterlets, which are intermediate in structure between the larger ones that we have been discussing, and an ordinary crater rill. One diameter west of Posidonius is a winding rill of the ordinary type at the north and south, but wider in the middle section, and analogous to the grooved valleys in appearance. There can be no question but that all of these valleys are due simply to confluent craters which have sprung up along the line of a submerged volcanic crack.

There remains one other lunar marking, and one only, which has been sometimes suggested as due to a gigantic meteorite, or the nucleus of a comet. This is the Valley of the Alps. It is 95 miles long, and at a maximum six miles wide. Except where crossing the Alps themselves it is a thousand feet deep. It connects the Mare Frigoris with Imbrium by a continuous, flat, nearly straight channel. Comparing it with terrestrial formations, we find that it is one-fifteenth of the length of the Red Sea, one-thirtieth its breadth, and one-fifth of its depth. It shows no evidence of a crater, nor of the ploughing up of rocks by a giant projectile. It certainly is not a crater valley. It appears to be simply a crack across the narrow strip of the original surface crust separating the two maria, and was partly filled, and perhaps enlarged, by liquid lava from beneath. During a favorable libration the whole length of its floor can be seen from end to end, with the exception of a very short section hidden behind the volcanic peak Mont Blanc δ. This peak contains two minute summit craters each 3000 feet in diameter. The floor of the valley contains a string of somewhat larger craters, which are just visible, or partly visible, when favorably situated, over the southern edge of the floor, in the widest portion of the valley. Beyond them a narrow rill extends along the middle of the floor. It was first described in *H. A.* **32**, 84, and was subsequently independently discovered by Perrine, who gives a careful drawing of it in these PUBLICATIONS, 1904. It should be looked for between co-longitudes 0° and 60° and is most easily seen in front of a diamond-shaped marking where the valley first enters the Alps. The valley then narrows and again widens for a short distance. Here the rill as it crosses the center of the floor is really a delicate test object, but can be held with seeing 10, and a power of 430. It can hardly be over 500 feet in width at this point, and is perhaps not over two hundred.

In conclusion we may say that as far as our investigations go, it appears not only that the great craters which the meteoric theory was invoked to explain are not caused by meteors, but that none of the other markings supposed to be so caused show any evidence whatever of having a meteoric origin.

Mandeville, Jamaica, B. W. I.
February 26, 1920.

NOTES ON THE PROBLEM OF THE ORIGIN OF THE LUNAR CRATERS

By W. W. Campbell

In recent years I have been deeply interested in the so-called Meteor Crater in Central Arizona. This crater, situated about twenty miles west of Winslow, and six miles south of the main line of the Santa Fe Railway, is four-fifths of a mile in diameter at the rim, its present depth is approximately 500 feet, and it has a general form resembling in all respects that of the lunar craters which are comparable in size to it. The Arizona crater is familiar to geologists; several geologists have visited the crater and have made extensive studies of it. The literature of the subject, embracing full two scores of papers, is due almost wholly to those whose chief interests are geologic. Their conclusions as to the origin of the crater are widely different. Gilbert, who was the first to study the subject thoroly, and Darton, whose papers are amongst the most recent, favor the hypothesis of an internal-explosion origin. Other geologists, notably Fairchild and Merrill, favor strongly the idea of origin by meteoric impact. Barringer, of Philadelphia, whose commercial company acquired legal title to the region containing the crater, and who made large expenditures of time and money in drilling in the crater bottom for meteoric iron and other valuable metals, holds firmly to the meteoric hypothesis. Astronomers have not, in my opinion, given the crater the attention which it deserves from them. To the best of my knowledge no astronomer has visited the crater, and its existence and character have not been recognized in astronomical text books. It is hoped that this neglect may soon be remedied.

My interest in the mooted question of the origin of the meteor crater renewed the interest which I felt in the origin of the lunar craters in the 1890's, when engaged in showing the Moon thru the 36-inch refractor to many thousands of Saturday evening visitors. At that time it did not occur to me that the volcanic origin of the lunar craters was in serious doubt, and I did not think of reviewing the subject in print. Since then, several published articles have seriously questioned this explanation of the crater origins. Knowing that I have in the past year been considering the probable origin of the lunar craters, in search for assistance in solving the problem of the origin of the Arizona crater, the editors of these PUBLICATIONS requested me to contribute an article on this subject to the present lunar number of this journal. It is not my purpose to attempt an exhaustive study of the lunar craters, but merely to call attention, under the heading of "Notes," to some of the less familiar, but possibly more important, pieces of evidence as to their origin.

Two hypotheses as to the origin of the lunar craters are well-known:

1. They are a result of volcanic activity on the Moon—just as terrestrial volcanoes are one of the results of volcanic activity on the Earth.
2. They are a result of collisions of rapidly-travelling meteoric bodies with the Moon.

The first hypothesis is more than two centuries old, and is favored by the great majority of astronomers who have given thought to the subject. The second hypothesis appears to date from Proctor, in 1873; it is preferred by a few astronomers, apparently by a larger proportion of geologists, and by many others interested in the physical sciences. References to one or both of the hypotheses are numerous in the astronomical literature of the last half century, but philosophic treatments of the problem, presenting the pros and cons of both hypotheses, without prejudices as to the final results, are scarce. In *Popular Astronomy*, **18**, 137-144, 1910, See has marshalled the leading arguments in favor of the meteoric hypothesis. In *Proceedings American Academy Arts and Sciences*, **47**, 730-733, 1912, Elihu Thomson makes a strong case for the same hypothesis.

It seems to me a mistake to argue for either origin exclusively. May not both sources have their representative craters? Existing telescopes do not let us examine the smaller craters in such detail as to enable us to assign their origins to their true causes. To be visible at all, a crater must apparently have a diameter of the order of a quarter of a mile and the illumination by the Sun must be just right, and for craters even one or two miles in diameter the details of structure are thus far almost as a sealed book.

Millions of meteors collide with the Earth's atmosphere every twenty-four hours, but very few of these get thru to the Earth's surface. Only one known terrestrial crater, the small one in

Arizona, seems to admit the possibility of a meteoric origin. The Moon, on the contrary, is practically without atmosphere, and hundreds of thousands of meteors probably collide with its surface every terrestrial day. The scarcity of great meteoric craters on the Earth is not to be explained by the resistance of the atmosphere to meteoric bombardment: meteors massive enough and speedy enough to create great craters on the Moon would pay no appreciable attention to the Earth's atmosphere. They would come thru the atmosphere, to the rock or water surface of the Earth, with speed and mass not appreciably reduced. If the lunar craters are really of meteoric origin, then the Earth must likewise have possessed in profusion meteor craters of great size. As we have said, not one such large crater is known to exist today. If they existed in past ages, they must have been obliterated by erosion, sedimentation, flows of molten rocks, or other results of meteorologic and geologic forces. The Moon, free from appreciable water and air, would doubtless give its craters much longer life.

We shall consider only the larger craters of the Moon. Their visible details afford a basis for testing hypotheses and drawing conclusions.

There appear to be no reasons for questioning that many truly geologic forces have been prominent in shaping the Moon's destiny. The lunar mountain ranges are in many respects comparable with terrestrial ranges. There are geologic faults, as on the Earth, and perhaps on a larger scale than with us; for example, one of the most conspicuous features of the Moon is an apparent geologic fault sixty miles long, approximately 1,000 feet high, situated about fifty miles easterly from the crater Thebit; it is known as the Great Wall. Many of the *maria* or lunar "seas," are in my opinion overflowed areas,[1]—just as immense terrestrial areas were overflowed by molten lava. The *maria* contain the remnants of many craters in which only the summits of the crater rims continue unsubmerged. Indeed, there are many cases in which only the high points of crater rims project above the submerging materials.

In the *maria* there are cases of apparent radial flows from craters which cease suddenly, apparently due to the flooding of the lower surrounding country by molten, flowing materials. Cassini and, less striking, Archimedes are examples. Aristillus, on the contrary, is surrounded by long radiating streamers whose outer ends have not been overflowed, thus suggesting that in this crater we see the results of the latest activity in this region. In Mare Humorum, admirably pictured by the Paris charts, plate XL, a lava flow has submerged those sections of the rims of the craters Lee, Doppelmayer, Gassendi, and Hippatus, which face the *mare*. The "flow marks" on the *mare* surface seem to be visible—as if the origin of flow had been more or less central in the *mare*. The eastern edge of Mare Crisium affords good examples of submerged craters, and likewise of flow marks. Near the south end of Mare Nectaris a flow has apparently submerged the north wall of the crater Fracastor, or possibly has melted the wall down. There are numerous cases of craters almost wholly submerged in the Ocean des Tempêtes, Paris chart LXII, and in the Mer des Nuages, Paris charts XIV and XIX. An excellent example is the extreme top of a large crater rim showing thru the submerging stratum at a point about two-fifths of the way from Eratosthenes to Archimedes.[2] The remains of submerged craters are especially numerous in Mare Nubium; the crater Kies is a prominent example—Paris chart VIII. Scores of similar cases can be found by examining the numerous lunar *maria* when the illumination of each is just right.

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[1] Professor E. W. Brown has called my attention to Franz's map of Average Levels of the lunar surface, in Koenigsberg *Beobachtungen*, **38**, 1899. This map shows that the southwest half of the visible hemisphere of the Moon, which is rich in craters and poor in seas, is more elevated than the northeast half, which is poor in craters and rich in seas. This is in harmony with the ideas that the southwest half in general has been elevated by the volcanic activities which accompany crater formation and that the northeast half should be the scene of greatest lava overflows.

The number of active volcanoes on the Earth in the last hundred thousand years was probably in excess of a thousand. The number positively known to have been active in historical times exceeds three hundred. Inasmuch as the levelling influences on the Moon are comparatively feeble and inactive, and the existence of mountains, geologic faults, and geologic flows can scarcely be doubted, is there cause for surprise that the number of lunar craters, if due to volcanic causes, operating thru many millions of years, should be numbered in the thousands?

If the impacts of great meteors with the lunar surface have been as numerous as the number of existent craters, should we not expect abundant evidences of impacts at all angles of incidence, varying from the tangential to the vertical? To the best of my knowledge and judgment there is only one feature of the lunar surface which suggests an impact differing appreciably from strikes in directions making small angles with the perpendiculars to the surface. In the Valley of the Alps we seem to have a collision effect, due to a massive meteoric body, possibly a mile or two in diameter, which all but missed the Moon, and therefore struck the lunar body in a direction nearly coincident with that of a tangent to the surface. The lunar Alps, about ninety miles wide at the point concerned, are ploughed nearly thru and down to "sea level," so to speak. The resulting Valley of the Alps, following Webb's description, is a great cut in a straight line thru the very loftiest part of the range, 83 miles long, 3½ to 5¾ miles broad, with precipitous sides and a depth of at least 11,500 feet. The bottom of the Valley is described as flat, but it is said that Klein saw what he called the results of landslides from the edges of the Valley. It is as if a great meteorite, travelling northerly over Italy, had struck the southern flank of the Alps at Como and ploughed its way horizontally thru the Alps as far as Lucerne. It is as if a great meteorite had ploughed its way thru the Sierra Nevada range in California, from the foothills east of Fresno easterly thru the Mount Whitney region to the floor of the valley on which the village of Lone Pine is situated. There may be a lingering doubt as to whether a great metallic meteorite travelling with a relative speed of forty miles, more or less, per second could save itself from volatilization or other destructive consequences while penetrating and overcoming the resistance of a great mountain range on a course of 83 miles. There would probably also be a tendency, during the several seconds occupied in the operation, for the projectile to strike a glancing blow or to break into fragments. It is possible that the mathematicians could deduce suggestive alternatives as to the consequences of an impact of the character and magnitude described.

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[2] See Plate IV of this number.—Editor's note.

There appear to be no lunar features clearly illustrating the effects of collisions by massive meteoric bodies whose angles of incidence lie between that assumed to have attended the formation of the Valley of the Alps and those postulated as the sources of the lunar craters. This is a fact in strong opposition to the impact theory of crater origin.

A great many laboratory experiments have been made by throwing or firing projectiles of various kinds and sizes upon resisting surfaces of different character, in order to study the forms of the resulting craterlets. These experiments have led to interesting results, but I do not believe there is any chance that they afford serious evidence as to the origin of any lunar craters large enough to be seen with telescopes, say one thousand feet in diameter and greater. A laboratory crater, whose diameter is only a few inches or a foot or two, must not be expected to tell us much about the origin of a crater 250,000 feet (50 miles) in diameter. A laboratory crater may have a central peak an inch or two or three inches high; will that tell us anything of value as to the origin of central peaks 6,000 feet high in lunar craters? By far the most interesting laboratory experiments of this nature conducted to date were those described by Ives in the *Astrophysical Journal* for November, 1919, in which the origins were the explosions of powerful bombs dropped upon the Earth's surface from airplanes. The largest craters developed by this means were of the order of one hundred feet in diameter, and possibly thirty feet in depth. Would we be justified in reasoning from these craters to the lunar craters, whose diameters are forty, fifty, and sixty miles, and whose depths are four, five, and six thousand feet? I think such comparisons must be of very limited value.

Advocates of the meteoric hypothesis of lunar origins have laid great stress upon the fact that many of the craters have central peaks three thousand, five thousand, or as much as seven thousand feet high. These central peaks are ascribed to reactions from the impacts, such as are illustrated by the central peaks in some of the small laboratory craters. While the number of these characteristic lunar peaks is very considerable, they are by no means the rule. The vast majority of lunar craters contain no central peaks. William H. Pickering is authority for the statement, further, that central peaks rarely occur in craters less than four miles in diameter. Do the central peaks in the little laboratory craters then mean anything in the lunar problem? If these central peaks on the Moon are reactionary results of impacts, why should they be so relatively few? Why should they not be the rule instead of the exception? If one general effect of impact is the throwing up of crater walls which have the common characteristics of steep interior slope and more gradual outer slope, why should they not have the common effect of central peaks? Another fact is, the existing peaks in many craters are not central. Further, in a considerable number of craters, there is not a single central peak, but two or more peaks near the center.

Let us imagine that a great meteor did actually produce by impact a lunar crater fifty miles in diameter, with a central peak five or six thousand feet high. What improbabilities does this assumption encounter? The crater wall and central peak, on this assumption, were created by one cataclysm, in a few seconds at the most. The materials left in the interior of the crater could scarcely avoid being reduced to liquid form. In any case the enclosing ring, a very steep mountain wall, so to speak, was thrown up suddenly and it stayed there. A central peak was thrown up suddenly and, notwithstanding its probable liquidity or viscosity, remained standing in opposition to the force of gravity. Are not these results highly improbable and essentially unthinkable? If, for any reason, the formation of the circular crater wall demands a long-continued molten state of the interior, what does the simultaneous formation of the central peak demand in this regard? We know that in many of the large craters, Tycho for example, the interior wall of the rim is beautifully terraced; why are not the central peaks similarly terraced?

While showing visitors thru the 36-inch refractor twenty-five and more years ago I was able to observe that some of the central peaks of lunar craters had light and shade effects on their extreme summits due to the existence of central summit craterlets, such as are known to exist in the summits of many terrestrial volcanic peaks. I made no notes on the subject, as I supposed these features were well known to students of the Moon. Last summer I recalled these observations and, realizing the critical bearing of such summit craterlets upon the theory of the origin of the central crater peaks and therefore upon the origin of the craters themselves, I searched the literature of the Moon carefully for published references to the subject. Gore says that "M. Gaudibert observed some high volcanic cones on the Moon with small crater openings on the top." These observations refer not to central crater cones, but to random peaks unconnected with craters. In William H. Pickering's *Lunar and Hawaiian Features Compared*, page 156, we read, "Between (the craters) Kies and Mercator is seen a comparatively small cone with a minute crater on its summit. It proves to be nine miles in diameter at the base, and two thousand feet in height, while the crater itself measures half a mile in diameter." This likewise refers to an outside or ordinary mountain peak. In November, 1919, I inquired of Professor Pickering whether his note books contained records of small craters at or very near the summits of the peaks which are central or nearly so in many large lunar craters. He responded that he had casually noticed a few such craterlets, for example at the summits of the central peaks in the craters Albategnius, Plinius, Capella, and Kant. He stated further that "outside of the craters there are many examples of high peaks which carry minute summit craters and are thus analogous to terrestrial volcanoes." His letter referred to eight such volcanic peaks located between Copernicus and Kepler. Shortly following the receipt of my inquiry Professor Pickering had a perfect night and he examined several of the lunar craters which had central peaks, with the result that he found summit craterlets in the central peaks of Timocharis, Herschel, Alpetragius and Pitatus.[3] He further made the important comments: "Since in most cases recorded these summit craterlets are less than a mile in diameter, running down to a size such that we can only just be certain of them, it is clear that there must be numerous others just beyond our range of vision." At about the same time Dr. Aitken and I examined the Moon on two evenings with the 36-inch refractor, and we had no difficulty in seeing several central-peak craterlets, of whose existence we had no prior knowledge. These craterlets seem to be most readily seen from eighteen to thirty-six hours after the Sun has risen on them or before the Sun will set on them. I am under great obligations to Professor Pickering for the valued information quoted above and for the privilege of using it.

Must we not agree that the unquestioned existence of craterlets in the summits of central crater peaks is absolutely fatal to the impact theory of the origin of those peaks, and at the same time in full and complete harmony with the hypothesis of the volcanic upbuilding of those peaks? It is known to all students of volcanism that central peaks in terrestrial volcanic structures are fairly numerous and that a very large proportion of them still retain undoubted evidence of summit craterlets, some of these craterlets in essentially perfect states of preservation.

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[3] See Table I of Professor Pickering's article for further details.—Editor's note.

One of the strongest arguments for the impact theory of crater origins on the Moon is based upon the fact that the floors of the craters are not only surprisingly far below the level of the tops of the crater rims, but are frequently several thousand feet below the level of the surrounding plains: the tremendous impacts of meteorites are credited with having excavated the resulting crater interiors to the great depths observed, the materials having been thrown out upon the adjacent areas. Could such a cataclysmic action, say one capable of excavating a crater fifty miles in diameter and five thousand feet deep in a second or two, or in a very few seconds at the most, avoid liquifying the crater interior? If a central peak were thrown up as a reaction effect, would it not be of viscous consistency and be pulled down immediately by lunar gravitation?[4] Could the interior wall of the rim remain so steep as we observe it? Could the interior walls of crater rims be terraced so markedly as we observe this effect in scores of craters, for example, Arzachel, Tycho, Copernicus, etc., if the impacts had emptied the crater bottoms down to their present low levels?

To me a vastly more probable description of the origin of a lunar crater and its central peak is the well-known one held by those who look with favor upon the hypothesis of volcanic origins. Whatever the beginnings of a volcanic lunar crater may have been there comes a time, probably early in its history, when the interior fills with molten materials which well up thru the central duct or neck that leads down to a considerable depth in the lunar body. This molten material overflows the rim of the crater, building up the rim, increasing the outer diameter of the rim structure, and some of the molten materials flow out upon the surrounding areas. The exterior walls of the rim cool and solidify, whereas the interior walls liquify from contact with the sea of molten matter, and the interior diameter of the crater ring increases. These processes probably continue intermittently thru long ages of lunar evolution. The molten sea of matter lowers in level thru the withdrawing of the materials into the Moon's interior; this is a process observed frequently in active terrestrial craters. The filling of the crater bowl probably occurs a great many times, with consequent overflowing and upbuilding of the rim and the increasing of its diameter by the melting down of its interior wall. Toward the end of the major stage of volcanic activity the successive fillings of the crater bowl probably are less and less complete, leading in many cases to the formation of terraces on the inner wall of the rim. When activity ceases the floor of the crater is left comparatively level. In many craters the volcanic activity is again renewed, but on a minor scale, with the effect that central peaks are built up by the escape of volcanic materials from the summit craterlets which terminate the central ducts or necks leading down into the body of the Moon. These processes could well and probably did consume many millions of years.

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[4] In the laboratory craters which had central peaks there was no liquefied or viscous condition and no appreciable gravitational component, to erase the diminutive central peaks.

A study of the so-called lunar rills leads unavoidably, I believe, to the conclusion that they are not the results of very oblique meteoric impacts, as some observers have suggested, but that they represent ordinary geologic processes. Many of the rills have craters situated upon them, in some cases at what may be called strategic points. The crater Hyginus is located precisely at a sharp angle in one of the most conspicuous of lunar rills—see Paris chart XLVI. There are other craters of fair size on the strongly curved rill east of the crater Bouillaud—Paris charts XLIX and VIII. The forms of both the rills referred to seem quite impossible on the basis of meteoric origin. The craters upon them suggest that the rills are the outward evidences of lines of weakness in the lunar surface strata.

The bright streamers which radiate from the craters Kepler, Olbers, Tycho, Copernicus, etc., are exceedingly interesting objects, and their presence must be accounted for by any successful hypothesis of crater origins. We may dismiss at once the idea that these brighter streaks are the results of the filling up of cracks radiating from the craters by materials of lighter color from the interior of the Moon. The streamers from several craters are remarkably straight (*i. e.*, arcs of great circles on the lunar surface) and in many cases these streamers run indifferently over level plains, crater bottoms, crater walls, and mountain structure. They are difficult to explain on other assumptions than that they are meteoric splashes or volcanic projectile discharges from craters. Some of these streamers, notably several extending out from Tycho, are many hundreds of miles in length. It is not very difficult to imagine that the brighter materials responsible for the streamers could have left their crater origins, as projectiles, with speeds sufficient to carry them over a large surrounding area of the Moon, where they are now observed. We need only to remember that the force of gravity at the lunar surface has but one-sixth its value at the Earth's surface, and that the motions of particles projected from the craters would meet with no atmospheric resistance, certainly with no appreciable resistance. Dust particles of low density would travel as far as massive pieces of high density. Comparatively low velocities of ejection from the craters would carry the ejected materials thru long distances, and the materials would be distributed on elemental lines, more or less long, which point toward the crater origins.[5] It is quite probable that a meteoric impact capable of producing the crater Tycho could eject fragments of matter from the crater with speeds sufficient to carry them to the extreme limits of the system of radiating streamers which have that crater for their focus. It is at least equally easy to imagine that a volcanic eruption in the crater Tycho could eject liquid or dust particles with speed sufficiently great to account for the distribution which we observe. Inasmuch as the walls, the terraces, and the central peak of Tycho are just what we should expect from a volcanic origin of the crater, need we struggle strongly against the volcanic eruption hypothesis of the remarkable system of streamers which center at that point? An examination of the immediate surroundings of Tycho shows that it has had little interference from activity in the neighborhood. Tycho is therefore the symbol of latest volcanic activity in the area which it occupies. This being true, we need not be surprised that the bright streamers radiating from Tycho are drawn across the more ancient topographic features upon which the projected Tychonic materials have fallen.

The streamers which radiate from Copernicus are not so straight as those from Tycho. Some of the streamer materials may have reached their present destination on ejection lines lying entirely above the surface of the Moon, whereas other materials may have followed the usual processes of volcanic flow. A critical examination of the Copernican region will show a few ancient craters, now almost totally submerged, across which the Copernican streamers have left their mark, whereas other craters in this region, apparently unaffected by the earlier submerging overflows, are untouched by the Copernican streamers under consideration. These perfect and complete craters are probably of more recent origin than Copernicus itself.

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[5] Professor E. W. Brown, when at Mount Hamilton recently, deduced from a hasty calculation that particles of matter ejected from a crater, such as Tycho, at a favorable angle with the lunar surface and a speed of the order of one and one-third miles per second, could be carried to points one thousand miles from the crater origin.

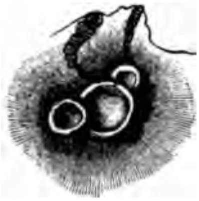

FIG. 1. Plan of the volcanic cone of the Island of Vulcanello (north of Sicily), showing three successive and overlapping craters.—From Geikie's Text Book of Geology, Vol. 1, p. 323.

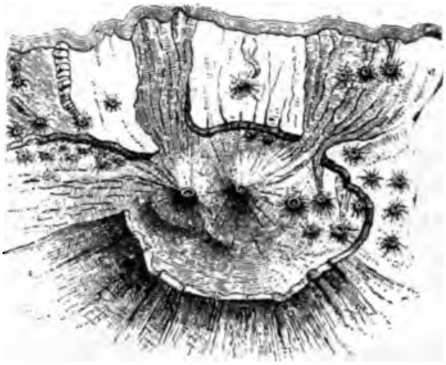

FIG. 2. Plan of the Peak of Teneriffe, showing the large crater and 32 minor craters.—From Geikie's Text Book of Geology, Vol. 1, p. 330.

It has been objected to the volcanic hypothesis of crater origin that overlapping lunar craters do not show the effects which volcanic flows inside of and over crater walls would lead us to expect. The first illustration in this paper, the plan of the volcanic cone on the island of Vulcanello, shows three successive and overlapping terrestrial craters with characteristics which should discount the objection.

It has been objected that the existence of great numbers of small craters on the floors of great craters and even upon the tops and inner and outer slopes of crater walls is opposed to the volcanic hypothesis and in favor of the meteoric. The second illustration in this paper, the plan of the Peak of Teneriffe, showing a large crater, as affected by meteorologic and other conditions, with as many as thirty-two minor craters superimposed upon the original crater, should remove the objection.

In concluding these notes on lunar characteristics, I am disposed to express my conviction that the principal surface features are the ordinary products to be expected from evolutionary processes purely geologic; that we may, on this hypothesis, assign to many surface features their relative ages; and that, while some small craters may possibly be the results of meteoric impact, the evidence for the volcanic origin of the larger craters is overwhelmingly strong.

THE SATELLITES IN THE SOLAR SYSTEM

By Seth B. Nicholson

The satellites of the solar system have made several important contributions to our astronomical knowledge. Perhaps their greatest achievement is in furnishing the most accurate means of weighing the planets. The discovery of the velocity of light resulted directly from the study of their motions and in many cases they have furnished the incentive for valuable research; but aside from any contribution to the larger problems of astronomy they will always be of interest as individual members of the solar system.

The principal data concerning the various satellites are presented in tabular form. The mean distance from the center of the primary is given in units of one thousand miles. For comparison the equatorial radii of the planets in miles and their sidereal periods are also included. The stellar magnitude is in general the mean visual magnitude reduced to the distance of the primary from the Earth at mean opposition, but the starred values for the faint satellites are photographic. In obtaining g, which is the visual magnitude that the satellite would have if at full phase and unit distance from the Earth and Sun, a color index of +0.8 has been used. The factor p, which is closely related to the albedo, is defined by Russell in the *Astrophysical Journal* for April, 1916. Except where starred, p is an assumed value. The diameters and magnitudes for *Titan* and the four large satellites of *Jupiter* are those adopted by Russell. The other diameters, except that of the Moon, have been computed using the formula $\log_{10}$ diam. (in miles) $= 2.92 - 1/5\, g - \log_{10} \sqrt{p}$. (An error of 0.05 in the value of p introduces an error of about 10% in the estimated diameters.) The estimated magnitudes of *Saturn's* satellites as given by Barnard make these objects from one to two magnitudes fainter than the photometric values given here. This difference, which is doubtless due in part to the nearness of the bright planet, gives an idea of the difficulty experienced in observing satellites.

On account of our nearness to the Sun, the Moon is by far the brightest satellite as seen from the surface of its primary. *Jupiter's* satellites are large, numerous, and some of them quite near the planet, but their light on *Jupiter*, even if all were in full phase at once, would be only one-third that of full moonlight on the Earth.

In size, however, several of the satellites exceed the Moon, the two largest being even larger than the planet *Mercury*. For those whose masses are known the densities are as follows: Moon, 3.4; *Jupiter* I, 2.4; *Jupiter* II, 3.1; *Jupiter* III, 2.1; *Jupiter* IV, 1.2; *Titan*, 5.6.

Several observers have seen indications of markings on the four large satellites of *Jupiter*. *Jupiter* I is most consistently seen as brighter at the poles than at the equator and this seems to be the best authenticated case of surface markings on any of the satellites other than our Moon. Soon after its discovery *Iapetus* was found to vary in magnitude, being always brighter at western than at eastern elongation. The variation is about 1.7 mag. This is generally explained by assuming that the satellite always keeps the same face toward *Saturn* and that its surface is very uneven in brightness.[1] Several of the other satellites have been observed to vary, and in most cases the same explanation is plausible.

The motions of the satellites offer some very interesting problems in the study of the evolution of the solar system. *Phobos* is the only known case of a body revolving about its primary faster than the primary rotates on its axis. As seen from *Mars*, *Phobos* would therefore rise in the west and set in the east. The Moon and all the close satellites of *Mars*, *Jupiter*, and *Saturn* revolve in the same direction as the planets rotate. All of the satellites of *Uranus* move in a plane nearly at right angles to the ecliptic, but observations indicate that the planet's rotation is likewise in the same direction. In the absence of observations to the contrary *Neptune* is also assumed to rotate in the direction of revolution of its satellite, which, however, is retrograde. *Phoebe*, the outermost satellite of *Saturn*, and *Jupiter* VIII and IX are the only positive examples of a retrograde motion with respect to the primary's rotation. Most of the satellites move in nearly circular orbits almost in the plane of their planet's equator. The striking exceptions to this rule are the outer satellites of *Jupiter* and *Sâturn*. This seems to require for them a theory of origin or evolution different from that of the inner satellites.

A very interesting theory has been advanced by W. H. Pickering to account for the retrograde motions of these outer satellites. He assumes that the evolution of the solar system has been along the lines indicated by a nebular hypothesis and that when a planet is first formed its rotation is retrograde. In the early stages the outer satellites were formed. Then they were direct moving objects referred to the primary's rotation. Due to a tidal action between the planet and the Sun the direction of rotation of the planet has been reversed, leaving the old satellites as they were. This reversal came about by a change in the inclination of the planet's equator, which has turned completely over so that what is now its north pole was formerly the south pole. The direct moving satellites were formed, according to the theory, after this reversal had taken place. *Jupiter* VI and VII are, however, direct moving objects, with large eccentricities and inclinations, and at about the same distance from the primary as *Phoebe*. The more generally accepted theory is that the outer satellites, at least, have been acquired by capture, while the others have been formed in the regular evolution of the planetary system.

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[1] If we assume $p = 0.10$ for the faint side, the bright side would have $p = 0.53$. The corresponding value for the mean magnitude is $p = 0.23$. These large and small values are near the extreme limits of the observed value of p for other satellites. The assumed value for *Iapetus* at its mean magnitude, therefore, cannot be changed much without necessitating an unreasonable value for the bright or dark face.

The four distant satellites of *Jupiter* form two very similar pairs. *Jupiter* VI and VII have nearly equal periods, similar eccentricities, and at present their perijoves lie in opposite directions from *Jupiter*. Their orbit planes, while having inclinations similar in magnitude, are by no means coincident. The same relations hold for the motions of *Jupiter* VIII and IX. Since there is no known reason why these particular periods should be more stable than any other, a common origin is indicated for the members of each pair. This would seem to be opposed to the theory that they were captured, at least as individuals. Another interesting fact is that the two satellites differ in brightness by almost the same amount in each case.

The outer satellites are so far from their primaries that the perturbative action of the Sun is very large. In fact it may be shown that if it were not for their retrograde motions *Jupiter* VIII and IX could not be permanently held by *Jupiter*. The orbit of an object at the distance of *Phoebe*, however, would be stable even if its motion were direct. Perturbations change the orbits so much that it is almost impossible to think of them in the ordinary sense. For instance, the eccentricity of *Jupiter* VIII has been known to change from 0.50 to 0.23 during two revolutions of the satellite.

Many observers have searched carefully in the neighborhood of the planets for additional satellites. Thus far *Mercury* and *Venus* remain the only planets with no known attendants. At least two observers have reported a satellite for *Venus*, but the observations were never confirmed and are now thought to have been in error. W. H. Pickering found a 17th magnitude object, apparently a satellite of *Saturn*, on plates taken in 1904 and another on plates taken in 1900. Orbits were computed for each of the objects. The periods were the same, about 21 days, but otherwise the orbits could not have referred to the same object unless the perturbations of *Titan*, which was not far away, could have been responsible for the great changes. At later oppositions the positions indicated by both orbits have been searched carefully with no success, so that while a tenth and even an eleventh satellite of *Saturn* may have been observed its present orbit and position are unknown.

Neptune and *Uranus* are so far away that their satellite field could be covered by a single photograph with a large reflector so that it is fairly safe to say that they have no additional satellites as bright as 17 or 18 magnitude, unless they are hidden in the glare of the planet. The same conditions apply to *Mars*, whose satellite field is actually small on account of the small mass of the planet. In the case of *Jupiter* and *Saturn*, however, the distance at which a satellite might be found is very large. *Jupiter* VIII and IX, for instance, may be as far as three degrees from the planet. The motion of an outer satellite may be so nearly like that which an asteroid might have that its identification necessitates a fairly long series of observations. Many observers have found moving objects in the neighborhood of *Jupiter*, but the observations have been too few to decide whether they are satellites or asteroids. *Jupiter* VI is fairly bright, much easier to see than *Jupiter* V, and the only reason it escaped detection so long was on account of its great distance from the planet. It is quite possible, therefore, that *Saturn* and *Jupiter* have more satellites fainter than the 16th magnitude.

SATELLITES OF THE SOLAR SYSTEM

Name	Mean Distance in Thousands of Miles	Sidereal Period		Stellar Magnitude	g (Absolute Magnitude)	p	Diameter in Miles	Discoverer	Date
THE EARTH $\left\{\begin{array}{l}3{,}963 \text{ miles}\\ 23^h56^m\end{array}\right.$									
The Moon	239	27^d	8^h	−12.6	+ 0.4	0.10*	2160		
MARS $\left\{\begin{array}{l}2{,}274 \text{ miles}\\ 24^h37^m\end{array}\right.$									
Phobus	5.8		8	+12.5	+13.0	0.13	7	Asaph Hall	1877
Deimos	14.6	1	6	+12.8	+13.3	0.13	5	Asaph Hall	1877
JUPITER $\left\{\begin{array}{l}45{,}128 \text{ miles}\\ 9^h55^m\end{array}\right.$									
V	113		12	+13.	+6.	0.15	150	Barnard	1892
I (Io)	261	1	18	+ 5.5	− 1.2	0.46*	2110	Galileo	1610
II (Europa)	415	3	13	+ 5.7	− 1.0	0.51*	1870	Galileo	1610
III (Ganymede	664	7	4	+ 5.1	− 1.6	0.30*	3270	Galileo	1610
IV (Callisto)	1167	16	18	+ 6.3	− 0.4	0.11*	3140	Galileo	1610
VI	7400	266	00	+13.7	+ 7.0	0.15	90	Perrine	1904
VII	7600	276	16	+17. *	+ 9.	0.15	35	Perrine	1905
VIII	14600	739		+17. *	+ 9.	0.15	35	Melotte	1908
IX	14800	750		+18.6*	+11.1	0.15	15	Nicholson	1914

SATELLITES OF THE SOLAR SYSTEM (Continued)

Name	Mean Distance in Thousands of Miles	Sidereal Period		Stellar Magnitude	g (Absolute Magnitude)	p	Diameter in Miles	Discoverer	Date
SATURN 38,228 miles $10^h 14^m$									
Mimas	117		23	+12.1	+ 2.5	0.20	600	W. Herschel	1789
Enceladus	157	1	9	+11.6	+ 2.0	0.20	750	W. Herschel	1789
Tethys	186	1	21	+10.5	+ 0.9	0.25	1110	J. D. Cassini	1684
Dione	238	2	18	+10.7	+ 1.1	0.25	1010	J. D. Cassini	1684
Rhea	332	4	12	+10.0	+ 0.4	0.25	1400	J. D. Cassini	1674
Titan	771	15	23	+ 8.3	− 1.3	0.33*	2670	Huygens	1655
Hyperion	934	21	8	+12.9	+ 3.3	0.20	410	G. P. Bond	1848
Iapetus	2225	79	22	+10.9	+ 1.3	0.25	930	J. D. Cassini	1671
Phoebe	7300	523	16	+17. *	+ 7.	0.15	90	W. H. Pickering	1898
URANUS 15,097 miles 11^h									
Ariel	120	2	12	+15.	+ 2.	0.25	650	Lassell	1851
Umbriel	167	4	3	+15.	+ 2.	0.25	650	Lassell	1851
Titania	273	8	17	+14.5	+ 1.8	0.25	750	W. Herschel	1787
Oberon	365	13	11	+14.7	+ 2.0	0.25	650	W. Herschel	1787
NEPTUNE 17,412 miles Unknown									
(Nameless)	222	5	21	+13.6	− 1.1	0.33	2430	Lassell	1846

VOYAGES TO THE MOON

By Heber D. Curtis

> ". . . Yet I do seriously, and upon good Grounds affirm it possible to make a Flying-Chariot; in which a Man may sit, and give such a Motion unto it, as shall convey him through the Air. And this perhaps might be made large enough to carry divers Men at the same time, together with Food for their *Viaticum*, and Commodities for Traffick. . . .
>
> So that notwithstanding all these seeming Impossibilities, 'tis likely enough, that there may be a Means invented of Journeying to the Moon; and how happy shall they be, that are first successful in this Attempt?"

Thus wrote the Right Reverend John Wilkins, Lord Bishop of Chester, in 1638.[1] The Bishop's prophetic vision of the modern air plane, and his views regarding the Moon as a possible abode of life, rest upon arguments derived largely from the Fathers of the Church, and there are few pages of this interesting old work without a Latin, Greek, or Hebrew quotation. It is doubtful whether there was in existence in the world at this time a telescope with an aperture as large as three inches, and speculation could still be untrammeled in seeking explanations of the lunar craters and "seas."

The march of geographical knowledge has made it increasingly difficult for the modern novelist to find suitable locations for a new Atlantis or Utopia. Swift had nearly the entire globe from which to select the localities of his Brobdignag and Lilliput. But Tibet, Central Australia, the wastes of inland Arabia, or the Gran Chaco, are no longer available. Central Africa is no longer a blank on our maps; Amundsen and Scott have made impossible the south polar "depression" in which were placed the strange, antithetical, pleasure-hating, misery-loving people of "A Strange Manuscript Found in a Copper Cylinder." The lot of the speculative novelist is now indeed a hard one.

Mars, of course, is still available, now that the Earth is so completely criss-crossed with explorers' tracks, but the difficulties of transportation or communication form a potent deterrent, in spite of sensational press reports of mysterious wireless signals.

Strange to say, not even the great astronomical progress of the past half-century has completely removed the Moon from the field of fiction as a suitable location for the strange or unknown. Perhaps the most interesting of all the various "trips to the Moon" in literature, H. G. Wells' "First Men in the Moon," appeared as late as 1901.

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[1] The Discovery of a New World; Or, a Discourse tending to prove, that 'tis probable there may be another Habitable World in the Moon. With a Discourse on the Possibility of a Passage thither. London, 1638.

Earliest of all the lunar journeys was Thomas Godwin's "The Man in the Moone; or, a Discourse of a Voyage thither by Domingo Gonzales," written about the year 1600, but published posthumously in 1638. Somewhat vague as to means of reaching the Moon, as have been, of necessity, all novelists save Verne, Godwin's accounts of the curious, winged, but man-like inhabitants, their life and government, are witty and full of interest. Godwin was one of the earliest supporters of the Copernican theory, and his account of this voyage to the Moon is believed to have given Swift his idea of the floating island of Laputa.

Later, and probably suggested by the works of Wilkins or Godwin, came Cyrano de Bergerac's "Histoire comique, ou voyage dans la Lune," published in 1662.

The purpose of these earlier works was, in general, satirical, contrasting lunarian customs and ethics with our own. It remained for Jules Verne (1865) and H. G. Wells (1901) to give an air of plausibility to their stories by drawing upon all the resources of science or pseudo-science in the methods employed for reaching our satellite. All remember Verne's device of an enormous cannon, located in Florida, which shot the voyagers to the Moon in a mighty steel projectile, the details of which seem quite medieval to the reader versed in the mechanical progress of the half-century which has elapsed since Verne wrote. Wells made use of a great steel sphere, endowed with a sort of mysterious negative gravity. His Lunarians, insects in form, differentiated in structure far more than ants or bees for their places in the lunar kingdom, lived in caves far beneath the actual surface of the Moon, where the atmosphere was dense enough to support life.

Edward Everett Hale's "The Brick Moon" (1873), a delightfully whimsical tale, deals, not with a journey to the Moon, but with a hollow brick (!) moon two hundred feet in diameter, which, with its passengers, became a satellite moving close to our Earth's surface.

Last of all, tho earlier in point of time, come two works of a different nature. These are Edgar Allen Poe's "Unparalleled Adventure of one Hans Pfall," published in 1835, and Richard A. Locke's "Moon Hoax," published in the New York ***Sun*** about three weeks after the appearance of Poe's story, and doubtless suggested by it. Poe ends his tale of Pfall's balloon voyage to the Moon in such a way that there is no doubt of its character as a hoax. Locke's, however, had such verisimilitude when viewed in the light of the rather crude science of that date, that it was accepted without question by thousands, and forms perhaps the most successful and certainly the most famous hoax ever perpetrated. Locke was at that time the editor of the New York *Sun*. The public knew that Herschel had gone to the Cape of Good Hope for astronomical observations with a powerful telescope, and was accordingly ready to believe almost anything about him and his results, as long as it appeared to have any reasonable scientific consistency, a quality which Locke very cleverly incorporated in his account. Even today this delicious hoax forms most entertaining reading, and some details from the little pamphlet, now quite rare, may be of interest to readers of the PUBLICATIONS. The title runs:—

> History of the Moon
> or an account of the
> Wonderful Discoveries
> of
> Sir John Herschel,
>
> Who, by means of an Object Glass weighing Seven Tons, with a magnifying power of 42,000 times, has been enabled to discover in the MOON, Rocks, Trees, Flowers . . . and more wonderful still, intelligent *winged* beings, Male and Female, who fly about, and walk erect like men.

The object glass was stated to be twenty-four feet in diameter, and the image in the focus was illuminated by an oxy-hydrogen light, *to make it bright enough to magnify again*, so that a power of 42,000 was attained, a device which reads plausibly yet—to one who knows no optics. The lunar inhabitants were seen to possess wings, were about four feet high, and of unusually intelligent countenances! This supposititious letter of Herschel's was accepted by the press of the world, printed and reprinted, widely discussed among scientists, and almost universally believed. It was not until Sir John Herschel had published an authentic account of his observations at the Cape that all faith in the hoax was abandoned.

Recent reports in the daily press, sent out under the auspices of the Smithsonian Institution, describe a new type of rocket for which the claim is made that it is theoretically possible, by its means, to reach the Moon. Doubtless most of those who have read this announcement have been irresistibly reminded of Jules Verne's moon-reaching projectile. Not a few, perhaps, sharing the American public's universal distrust of all newspaper "science," have mentally classified the announcement as of precisely the same scientific value as Verne's famous story.

A brief outline of Dr. Goddard's[2] experiments on rockets and the theoretical conclusions reached by him may serve to make the matter clearer. Dr. Goddard's paper deals with experiments on the efficiency of various types of rockets, carried out in the physical laboratory of Clark University, under a grant of $5,000 from the Hodgkins Fund of the Smithsonian Institution. The investigation was in part preliminary to the design of a heavy, multiple-charge rocket for military use, and in part an attempt to provide means by which recording instruments could be carried to heights of fifty or more miles above the Earth's surface and thus obtain meteorological data of very great value.

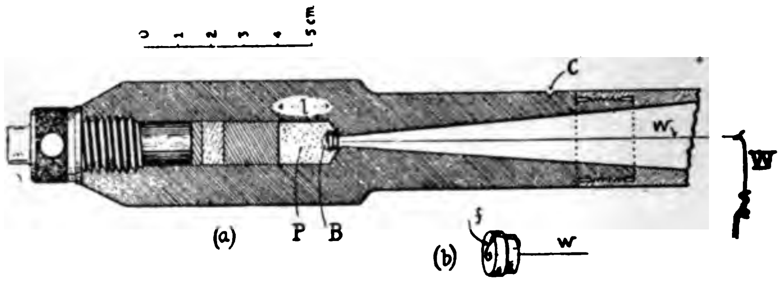

FIG. 1. Sectional View of Goddard's Experimental Rocket

The efficiency of an ordinary rocket is very low, not more than 2%. An improved type of rocket was devised by Dr. Goddard, shown in Figure 1. This was constructed of steel, with a tapered nozzle, so as to secure the advantage of the work done by the expansion of the gas of the discharge. The chamber, *P*, held varying amounts of smokeless powder. By various methods of measuring the recoil, and by many experiments, the efficiency of the rocket was determined both in air and in a vacuum.[3] In the most favorable cases velocities of gas discharge were obtained ranging from 7,000 to nearly 8,000 feet per second, a velocity higher than ever before secured by man for any appreciable mass of matter. Efficiencies of from 50% to 64% were found, indicating that the device has by far the highest efficiency yet attained for a heat engine, that of the Diesel internal combustion engine being about 40%.

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[2] A Method of Reaching Extreme Altitudes, by Dr. R. H. Goddard, Clark College, Worcester, Mass. Smithsonian Miscellaneous Collections, Vol. 71, No. 2, 1919.

[3] The effect of the air-recoil is negligible. Such a rocket will be practically as efficient in a vacuum as in air.

From these results, and from theoretical considerations, Dr. Goddard next calculates the initial mass of powder and rocket necessary to raise one pound of final mass to various heights. Taking the highest velocity of discharge secured in his experiments, and assuming that the rocket starts from sea-level, his results are:

Greatest altitude attained	Time to reach greatest altitude	Total initial mass required for one pound of final mass.
35 miles	144 seconds	3.7 pounds
115 "	266 "	6.4 "
437 "	475 "	12.3 "
infinity	...	1274 "

For reaching extreme altitudes, a system of multiple charges is planned for the rocket, by which charges of explosive are ignited in succession, and whereby useless portions of the powder chambers are also cast off, so as to provide for a relatively small final mass. It is found by calculation that a very small parachute device will be sufficient to provide for the safe descent of meteorological instruments, even if carried up several hundred miles.

Dr. Goddard deems it *theoretically* possible to send such a rocket beyond the force of the Earth's attraction, i. e., to infinity. The only way to tell whether such a projectile had actually passed beyond the Earth's attraction would be to "fire" it against the dark surface of the new Moon, provide sufficient extra powder to produce a flash on impact, and watch for this flash with a telescope. This would require a rocket of an initial mass of about seventeen tons. This idea is suggested as a speculation, rather than as a possibility, by Dr. Goddard.

Even if it were possible to construct a rocket capable of passing beyond the influence of the Earth's attraction, there would be innumerable difficulties in actually striking the Moon. It would seem that the least inaccuracy of aim, the least irregularity of air resistance when near the Earth, failure to account precisely for the Moon's orbital motion or the Sun's disturbing attraction, or the least lateral or otherwise irregular impulse of an exploding charge, would cause the projectile to miss its target.

The experiments made by Dr. Goddard may conceivably be of great value, however, in exploring those remote regions of our upper atmosphere far beyond the present range of sounding balloons (about 20 miles). It should be emphasized, also, that the investigation is still in the experimental stage, and that no rocket of this type has yet been actually constructed.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1920

By Malcolm McNeill

PHASES OF THE MOON, PACIFIC TIME

Full Moon	May	2, 5^h47^m P.M.	Full Moon	June	1, 9^h18^m A.M.
Last Quarter	"	10, 9 51 P.M.	Last Quarter	"	9, 10 58 A.M.
New Moon	"	17, 10 25 P.M.	New Moon	"	16, 5 41 A.M.
First Quarter	"	24, 1 7 P.M.	First Quarter	"	22, 10 49 P.M.

The first of the four eclipses for 1920 will be *a total eclipse of the Moon* on May 2; the beginning visible on both sides of the Atlantic Ocean, the ending visible from western Europe to the eastern part of the Pacific Ocean. Circumstances of the eclipse are as follows, Pacific Time:

Moon enters penumbra	May	2, 2^h49^m P.M.
Moon enters umbra	"	2, 4 1 P.M.
Total eclipse begins	"	2, 5 15 P.M.
Middle of eclipse	"	2, 5 51 P.M.
Total eclipse ends	"	2, 6 27 P.M.
Moon leaves umbra	"	2, 7 41 P.M.
Moon leaves penumbra	"	2, 8 53 P.M.

The second will be *a partial eclipse of the Sun* on the night of May 17th-18th, Pacific Time. At its maximum it will be nearly total; but it will be visible only from the southern part of the eastern hemisphere. Australia will be the only large land mass in its track.

The summer solstice occurs June 21st, 9^h40^m A.M., Pacific Time.

Mercury on May 1st is a morning star, rising less than an hour before sunrise, too short an interval for naked-eye observation. Its distance from the Sun diminishes and superior conjunction is reached on May 25th, the planet becoming an evening star. The distance from the Sun increases until the planet reaches greatest east elongation, 25°41′ on June 29th. This greatest elongation is greater than the average, as it occurs only a few days before aphelion passage on July 10th. Soon after the first week in June the planet remains above the horizon more than an hour after sunset, and thruout the latter half of the month the interval is over an hour and a half. The planet is not quite as bright as it was during the preceding greatest east elongation in March, but its greater apparent distance from the Sun gives a much better opportunity for naked-eye view. The latter half of June affords the best opportunity of the year for seeing *Mercury* as an evening star. *Mercury* and *Venus* are in rather close conjunction on May 13th, but both are too near the Sun for naked-eye view.

Venus is still a morning star, but thruout the two months it is too near the Sun for naked-eye view. On May 1st it rises only about half an hour before sunrise and at the end of June it is only about three days from superior conjunction, being rather less than 1° west of the Sun.

Mars is in very fine position for evening observation, having passed opposition on April 21st and nearest approach to the Earth on April 27th. On May 1st it is well above the horizon at sunset and does not set until nearly sunrise. By the end of June it will set shortly after midnight. It is in the constellation *Virgo* and moves westward and northward about 9° up to June 1st. It then moves eastward and southward. Thruout the two months it is near the first magnitude star *Spica, α Virginis*, and is in conjunction with the star twice, on May 22nd when the planet is moving westward and on June 7th when moving eastward. On the first date the planet is about 2°30′ north of the star, and on the second date about 2° north. After the time of nearest approach to the Earth the planet's distance increases, rather slowly at first but by the end of June it has reached 78 millions of miles, an increase of 24 millions of miles since May 1st. Its brightness consequently falls off more than 50%, but even at the latter date it is more than a full magnitude brighter than *Spica*, the star being not quite a standard first magnitude.

Jupiter is still in fine position in the southwestern quadrant for evening observation. On May 1st it does not set until after 1 A.M. and on June 30th until nearly 10 P.M. It is on the border line between *Cancer* and *Leo* and moves about 9° eastward and 2° southward toward *Regulus, α Leonis*. On June 30th it is about 10° west and north of the star.

Saturn is also in good position for evening observation in the southern and southwestern sky. On May 1st it does not set until about 2.30 A.M. and on June 30th about 10.30 P.M. It is in the constellation *Leo*, moving about 2° eastward and 1° southward during the two months. On May 1st it is about 8° south and east of *Regulus*, and moves away from the star during the period. Its brightness is about the same as that of the star. The rings have begun to close up, and at the end of June the minor axis is only a little more than one-tenth of the major.

Uranus is not in good position for observation, rising at about 2.30 A.M. on May 1st and at about 10.30 P.M. on June 30th. It is nearly stationary in *Aquarius*, moving a fraction of 1° eastward up to June 10th and then moving a little westward for the rest of the month.

Neptune is in the neighborhood of *Jupiter*, but the eastward motion of the latter causes a considerable increase in distance.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE SPECTRUM OF NOVA LYRAE 1919

A spectrogram of the nova in *Lyra*, discovered by Miss Mackie from photographs taken at the Harvard College Observatory (H. C. O. Bulletin No. 705) was obtained by Joy on February 5th with the 100-inch telescope. On account of the low altitude of the star the exposure time was limited and the *H* and *K* lines of calcium do not appear on the negative.

The spectrum consists of a considerable number of bright bands superposed on a faint continuous background. The bright hydrogen bands are from 25 to 30 angstroms wide and are double, with a faint broad absorption line near the normal position. On the violet side are two widely separated absorption components of which the more refrangible is the broader. Some of the narrower and fainter bright bands are probably due to enhanced lines of iron and titanium. In the region λ4570 to λ4620 are a number of diffuse absorption lines which are perhaps due to oxygen and nitrogen lines, as has been suggested in the case of other novae by Baxandall and Stratton. The chief nebular line at λ5007 appears faintly on the photograph. The spectrum is in many respects similar to that of *Nova Aquilae* No. 3 about June 18, 1918, nine days after its maximum of light.

The following measures were made on the dark and bright lines and bands.

Hydrogen absorption lines:

Displacement at....	Hδ	Hγ	Hβ
First component....	−13.1A	−14.3A	−16.2A
Second component..	....	−27.5	−30.8

Absorption lines probably due to oxygen and nitrogen:

4573, 4579, 4585, 4592, 4602, 4615, 4622.

Bright bands some of which may be portions of the continuous spectrum:

4103 (Hδ), 4340 (Hγ), 4416, 4435, 4454, 4471 (He?), 4514, 4534 (Ti?), 4552 (Fe, Ti?), 4655±, 4861 (Hβ), 4924 (Fe?), 5006 (N1.)

The widths of some of the bands in angstroms are as follows:

Hδ (estimated), 20; Hγ, 25; λ4655, 57; Hβ, 29.

The band at λ4655 is complex and only the stronger portion is measured.

W. S. Adams.
A. H. Joy

The Spectrum of N. G. C. 1499

N. G. C. 1499 ($\alpha = 3^h 54^m$, $\delta = +36°$ for 1860, $\lambda = 129°$, $\beta = -12°$) is a mass of faint nebulosity sprawled over a space of sky two degrees by half a degree. The position angle of the longer diameter is roughly 120°, so the nebula lies approximately parallel to the Milky Way. It borders the southern margin of a dark lane, which, beginning to the northwest of the nebula, winds its way eastward and southward to lose itself in the vast dark clouds of *Auriga*. The position of the nebula is somewhat anomalous, for it lies neither conspicuously in, nor entirely out of the dark region, and a simple inspection affords no convincing proof of a relation with the lane. The brightest portion—that for which the N. G. C. position is given—is, however, clear of the lane and lies on a background of small stars. Photographs[1] have been published on various scales. Several dark markings and a general unevenness of density show on these reproductions, but as a whole the nebula has a curious lack of fine detail for one of this type.

The nebula is too faint to be studied with a slit spectrograph and ordinary exposures. An objective prism and rapid camera, however, show a bright-line spectrum with features of considerable interest. In January and February, 1920, I made four exposures with different combinations as follows:

6° Prism and 10-in. Cooke Lens	f/4.5.	5^h	exp.	Seed 30.
15° Prism and 10-in. Cooke Lens	f/4.5.	$4\frac{1}{2}^h$	exp.	Seed 30.
39° Prism and 4-in. Lens	f/1.8.	3^h	exp.	Seed 30.
25° Prism and 4-in. Lens	f/1.8.	3^h	exp.	Seed 30.

The images were all very faint, in fact it was found convenient to increase the contrast by making second negatives and superposing them. The negatives were studied in the usual manner by "blinking" them against direct photographs and superposing the direct image and successive spectral images, locating the wave-lengths by noting the positions of stars on their corresponding stellar spectra. Only two portions of the nebula were dense enough to give results—the brightest part, a wedge-shaped mass on the north following edge pointing to south following, and a fairly bright edge on the south preceding side.

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[1] Among others:
Barnard, *Publications of the Lick Observatory*, Vol. XI, plates 16, 17.
Roberts, *Celestial Photographs*, Vol. II, plate 22.
Palissa-Wolf, *Sternkarten*, Blatt 10.
Barnard discovered the nebula visually in 1885.

The following bright-line images could be seen:

N_1
N_2
$H\beta$
$\lambda 4686$
$H\gamma$
$H\delta$
$H\epsilon$

$H\beta$ and $H\gamma$ were about equally bright and about twice the intensity of the others, which were too faint to be readily arranged in order of brightness.

The 6° prism showed an additional blurred image, easily the brightest of the entire spectrum near the head of the hydrogen series. This was first thought to be due to the nebular lines at λ3727. Higher dispersion, however, broadened and weakened this image and presented it as a continuous spectrum beginning, as near as could be determined, at the head of hydrogen series and extending in the direction of decreasing wave-length. These strong ultra-violet radiations probably account for the fact that the bright line images are sharper in detail than the direct photographs.

Wright[2] has recently discussed this type of continuous spectrum, and has given reasons for thinking it due to the Balmer series of hydrogen. Altho he specifically refers to it only in describing spectra of planetaries, he remarks that it exists in many gaseous nebulae. In the light of Wright's discussion the phenomenon may be considered as one of the points of resemblance between the physical conditions existing in planetaries and in the great gaseous nebulae.

Edwin P. Hubble.

W Virginis

The typical Cepheid variable of the galactic system, with period of light variation greater than a day, is commonly found relatively close to the plane of the Milky Way. For 94 variables of this kind, whose distances and distribution in space are derived and discussed in *Mt. Wilson Contr.*, No. 153, the average distance from the galactic plane is only 150 parsecs, while for more than two-thirds of them the distance along the plane is in excess of 1000 parsecs.

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[2] *Publications of the Lick Observatory*, Vol. XIII, part VI.

In contrast to this remarkable galactic concentration of the typical Cepheid variable, many members of the other principal group of Cepheids (the "cluster" type, with periods less than a day), are found in high galactic latitude and linearly very far from the mid-galactic stellar regions. The average distance from the plane for 45 such variables is about 1000 parsecs.

The greatest radial distance from the Sun heretofore recorded for Cepheids of either group is 5880 parsecs, and the maximum distance from the plane is 5240 parsecs (RU *Bootis*, *Pub. A. S. P.*, **29**, 183, 1917).

A few faint variables that may be Cepheids of long period are found in high galactic latitude (*Mt. Wilson Contr.*, No. 153, Table II), but peculiarities of their light curves, periods or spectra, make it doubtful if their distances can be derived by means of the period-luminosity curve (*Mt. Wilson Contr.*, No. 151, Figure 1 and Table XI). Recent work on one of these stars, however, appears to establish its typical character and gives us the first galactic Cepheid of long period distinctly outside the equatorial section of the Milky Way. (There are, of course, many Cepheids of both groups in high galactic latitude in globular clusters, at enormous distances from the Milky Way.)

W *Virginis*, discovered by Schönfeld 54 years ago and since then the subject of more than twenty scientific papers, appears from the accurate photometric observations by Wendell at Harvard and from the recent discussion of the Harvard photographs by Chant (*Harvard Annals*, **80**, 221) to be a normal Cepheid variable with a period of 17.113 days. Some of the earlier observers obtained from visual estimates evidence of a symmetrical curve, others thought they found a pronounced secondary maximum. Neither of these characteristics appears in later investigations. As Chant's recent study of plates, extending over an interval of 25 years, is by far the most extensive investigation of the star, we may accept, for the present at least, his conclusion that the variability is typical.

From the equatorial co-ordinates, the photometric data, and the period-luminosity law we derive:

Galactic longitude		296°
Galactic latitude		+57°
Median apparent visual magnitude		10.3
Logarithm of the period		1.237
Absolute visual magnitude		−4.0
Radial distance from the Sun	parsecs	7,100
Distance projected on the galactic plane	parsecs	3,900
Distance from the galactic plane	parsecs	+6,000

From these results it appears that W *Virginis* is not only the most remote galactic Cepheid for which a distance has been definitely estimated, but is also at the greatest distance from the galactic plane as yet found for any isolated star.

HARLOW SHAPLEY

THE PARALLAXES OF N. G. C. 40 AND N. G. C. 2022.

The parallaxes of these two planetary nebulae were recently determined from 14 and 16 exposures, respectively. The results are:

$$\text{N. G. C. } 40 \quad \pi_{\text{rel}} = 0''.000 \pm 0''.003$$

$$\text{N. G. C. } 2022 \quad \pi_{\text{rel}} = +0''.008 \pm 0''.004$$

To obtain absolute parallaxes about 0″.002 should be added to the relative values. The angular diameters given by Curtis are 60″ and 28″; his estimates of the photographic magnitude of the central stars are 10 and 13.

A. VAN MAANEN.

THE SPECTRUM OF THE COMPANION TO CASTOR AND OF W. B. 16^h 906.

Common proper motion of 0″.20 links the 9.5 magnitude companion to *Castor* ($7^h28^m.2$, $+32°.6'$: 1900) altho its distance is 73″. Also Fox[1] has found the parallax to be 0″.114, which is comparable with, 0″.075, the mean found by several observers for the components of *Castor* itself.

The spectrum of the companion has been photographed at this observatory for determining its absolute magnitude and parallax. Plates taken in 1916 with the 7-inch camera and 60-inch telescope indicated that the star was a binary of late type with both components showing and with bright hydrogen lines but the greater dispersion available with the 100-inch reflector has made it possible to analyze the spectrum with much more certainty.

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[1] *C. R.* **168**, 1096.

It is now evident that the components of the binary are nearly alike in type and of equal brightness. The spectra are characteristic of dwarf K_8 type except that hydrogen has sharp bright lines in both. The H and K lines of calcium are also bright but on account of the weakness of the spectra in the violet portions we cannot be certain that they show in both stars.

There are traces of the M type bands but they are hardly strong enough to place the star in class M. The spectrum differs in many respects from that of the Md type variables of long period, which are probably giant stars. The bright hydrogen lines have the same displacement as the absorption lines and $H\beta$ is stronger than $H\gamma$. So far as we know there has been no suspicion of variability of its light altho it has doubtless been seen very often by double star observers and others in setting on *Castor*.

The few plates so far obtained seem to indicate that the period of the binary is surprisingly short for a late type star. Photographs taken on successive nights give the complete ranges from single lines or superimposed spectra to a separation of 230^{km} in the lines of the two components. It is apparent that the period must be as short as four or five days unless the eccentricity is unexpectedly large. It is hoped that sufficient plates may be obtained to determine its orbit at least approximately.

The radial velocity from one plate taken with the 100-inch telescope and 18-inch camera when the spectra seemed to coincide best measured $+3^{km}$ which agrees with the mean of the velocities of -1.0^{km} and $+6.2^{km}$ for the center of mass of α_1 and α_2 *Geminorum*.[2]

The absolute magnitude of each component of the companion as determined from the spectrum is 9.5. The combined apparent magnitude is 8.6 or 9.4 for each star, supposing them to be of equal brightness. We would then have $0''.105$ for the spectroscopic parallax which confirms the trigonometric parallax.

The proper motion, parallax and radial velocity altogether make it certain that the faint companion in some way belongs to the *Castor* group in spite of its considerable distance, which must be of the order of 1000 astronomical units.

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[2] Curtis, *L. O. B.*, 4, 55.

We then have in this interesting system three visible stars whose apparent magnitudes are 2.8, 2.0 and 9.5. The two bright stars have spectra nearly alike of type A_0 and their intrinsic brightness places them among the brighter stars of that class. They form the well known visual pair Σ 1110, whose period has been computed to be 347 years[3] and whose distance is about $6''$. Each of the three visible stars is itself a spectroscopic binary, the periods being 2.9, 9.2 and 4± days respectively. There is a remarkable range of mass, spectrum, luminosity and orbital character in the different members of the group.

The only other star of low luminosity and late type of spectrum with bright hydrogen lines which has come to our knowledge is W. B. 16^h 906=B. D.$-8°$ 4352 ($16^h50^m.1$, $-8°9'$: 1900, $8^m.8$). Except for the bright lines this star would be classified as Ma with fairly strong bands. It has a large proper motion of $1''.27$ and a measured trigonometric parallax of $0''.150$. The low luminosity lines are exceedingly strong, giving a spectroscopic parallax[4] of $0''.174$. The general characteristics of the spectrum are of the dwarf type similar to that of the companion to *Castor*. Its radial velocity determined from low dispersion plates is $+3^{km}$ and appears to be constant.

In order to determine whether or not there might be changes in its spectrum or brightness Miss Cannon at our suggestion kindly examined the Harvard plates of this star. She found the spectrum on a number of plates but, on account of the faintness of the star, the emission lines were uncertain on many of the plates and she could not be sure of the invariability of its spectrum. Her classification was K_5. On 28 Harvard Chart plates from 1899 to 1919 there was "no appreciable variation" in magnitude.

The Mt. Wilson photographs taken in 1914, 1916 and 1917 show no variation in the spectrum. The hydrogen lines are sharp bright lines on all of the plates, $H\beta$ being the strongest of the series. None of the plates is strong enough to show the H and K lines of calcium.

W. S. ADAMS.
A. H. JOY.

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[3] Doberck, *A. N.* **166**, 145.
[4] *Contributions of the Mt. Wilson Observatory* No. 142.

THE PLANETARY NEBULA I. C. 2003

The small nebula No. 2003 in Dreyer's *Index Catalogue* ($\alpha = 3^h 47^m 26^s$, $\delta = +33^\circ 27'.7$, 1860) was discovered by Espin[1] in 1907. He described it as about 5″ in diameter, slightly elongated north-south, equal in light to a 10th magnitude star, and suggesting a planetary. I find no mention of its spectrum in any publication and therefore offer the following data.

The nebula is in fact a planetary. It appears on two of my plates taken with objective prisms attached to a 10-inch Cooke lens of 45 inches focus. These plates are:

15° prism, 270^m exposure, Seed 30, spectrum unwidened.
6° prism, 300^m exposure, Seed 30, spectrum 0.4^{mm} wide.

Nine bright images can be well seen on a very faint continuous spectrum. With relative intensities, these are:

N_1	Intensity	15	H_γ	Intensity	3
N_2	"	8	H_δ	"	2
H_β	"	3	H_ϵ	"	1
4686	"	5	H_ζ	"	1
4363	"	1			

Two other exceedingly faint bright lines appear, as nearly as can be judged, in the position of the well known nuclear bright bands at 4471 and 4267. The scale is too small to distinguish with certainty between nucleus and nebula.

The spectrum as a whole is brighter than that of I. C. 351, which appears on the same plates.

Mt. Wilson Observatory. EDWIN P. HUBBLE.

TWELVE NEW VARIABLE STARS.

The following is a list of uncataloged variable stars collected while examining plates on the "Blink-mikroscope," for the most part at the Yerkes Observatory. At that institution I had the privilege of referring to the Bruce plates which Mr. Barnard very kindly always offered for the purpose of checking suspicious objects found on my own plates. In this way some idea could be immediately formed of the nature of the variability considered.

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[1] *Monthly Notices, R. A. S.*, 67, 360.

No.	1900.0		Observed Range in Photographic Magnitudes.
1[1]	$\alpha = 0^h 55^m 14^s$	$\delta = +60° \; 11'.0$	13 to fainter than 17.5
2[2]	5 22 8	−28 51 .2	9 to 12.5
3[3]	6 33 8	+ 9 5. 0	13 to fainter than 17.5
4[4]	6 34 7	+ 8 56 .3	16 to 17.5
5[5]	6 34 11	+ 8 56 .8	15.5 to 17
6[6]	6 35 35	+10 32 .1	13 to 15
7[7]	6 41 40	+ 8 7 .3	10 to 15
8[8]	18 23 45	−11 15 .1	12.5 to 14.5
9[9]	19 56 55	+22 50 .0	11 to 14
10[10]	21 33 6	+23 22 .7	12 to 17
11[11]	23 46 59	+55 29 .4	13.5 to 16. (Algol)
12[12]	23 47 35	+56 11 .2	13 to fainter than 18

EDWIN P. HUBBLE.

PHOTOMETRIC PARALLAXES OF NINE CEPHEID VARIABLES

The parallaxes and space co-ordinates of 139 Cepheid variables of the galactic system were published two years ago in *Mt. Wilson Contr.*, No. 153. Further photometric studies, mainly by Hoffmeister at Bamberg, make it now possible to add nine stars to the list. The periods, as usual, are known with much higher accuracy than the magnitudes at maximum and minimum, but unless the error in the median brightness exceeds half a magnitude, the mean error of the parallax is probably less than 25 per cent, that is, on the average less than 0.″0002.

Designation	Galactic		Period in Days	Med. Mag. Visual	Parallax	Distance (Unit is 100 Parsecs)		
	Long.	Lat.				Radial	Projected	From Plane
140 X Arietis...	137°	−40°	0.651	8.9	0″.0014	7.1	5.5	− 4.6
141 SS Tauri....	148	−38	0.370	12.2	0 .00032	31.2	24.6	−19.3
142 SW Tauri...	158	−29	1.584	9.4	0 .00083	12.0	10.5	− 5.8
143 RZ Tauri...	147	−18	0.172	10.0	0 .00083	12.0	11.4	− 3.7
144 —Aurigae ..	134	+ 1	18.356	9.2	0 .00022	45.5	45.5	+ 0.8
145 ST Tauri...	161	− 7	4.035	8.6	0 .00083	12.0	11.9	− 1.5
146 RW Cancri..	164	+43	0.548	11.0	0 .00052	19.2	14.0	+13.1
147 V Leon. min.	166	+58	0.544	10.7	0 .00060	16.7	8.9	+14.2
148 W Serpentis.	296	+57	17.113	10.3	0 .00014	71.	39.	+60.

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[1] 4 observations.

[2] C. D. − 28°.2169. Position from C. D. catalog. 3 observations.

[3] 30 observations. Period is about 9 months. Light curve is steeper on ascending side than on the descending side.

[4] and [5] 30 observations. Period is short or irregular.

[6] $6^s.2$ following, 113″ south of B. D. +10°.1221. 25 observations. Period is long.

[7] $14^s.1$ preceding, 82″ south of B. D. +8°.1496. 25 observations. Period is long.

[8] 9 observations. Period is long. Position estimated from the B. D. Chart.

[9] 23 observations. Period is long.

[10] 3 observations.

[11] Algol type. Faint on June 7, 1915, and February 27, 1916, hour unknown. $9^s.5$ following, 7′0″ north of B. D. +55°.3036.

[12] 40 observations. Period about 12 months.

The median absolute magnitude can be computed from the parallax and apparent magnitude, or read from the period-luminosity curve (*Mt. Wilson Contr.* 151). The anomalous position in space of W *Serpentis* has been discussed in a preceding note. A few points relating to the other stars of the list may be worth mentioning.

1. The period of SW *Tauri* is very uncommon, coming between the values typical for the long and short period groups of Cepheids. Its galactic position suggests affiliation with the short period group.

2. The period of RZ *Tauri*, four hours and eight minutes, is the shortest on record for a cluster type variable with the single exception of XX *Cygni*, period three hours and fourteen minutes.

3. The two long period Cepheids, 144—*Aurigae* and ST *Tauri*, show the concentration to the galactic plane characteristic for such stars, W *Virginis* being the only conspicuous exception. Similarly, the five variables of the short-period group illustrate the wide distribution in galactic latitude and in distance from the galactic plane that is usual for short-period Cepheids.

Harlow Shapley.

Changes in the Spectrum of Omicron Ceti.

Observations of the spectrum of *Omicron Ceti*, made during the period of its decline in brightness from the maximum of the summer of 1919, show that the changes which occurred up to the middle of December are such as are well known from previous investigations. As the star grows fainter the banded character of the spectrum becomes more pronounced, especially in the region λ4400-4600; the relative intensity of the hydrogen lines changes, Hγ becoming stronger with reference to Hδ; λ4227 of calcium and the chromium lines λ4255 and λ4275 become broader and stronger, and many other low temperature lines increase in prominence; finally a number of narrow bright lines develop, most of which may be identified with low temperature lines of various elements, more especially of iron. The magnesium line at λ4571 becomes much the strongest of these lines by the time the star has decreased considerably in light. A spectrogram taken on December 12 shows these characteristics plainly, the hydrogen lines, like the bright low-temperature lines, being narrow and well-defined.

A very marked change is shown on the first photograph of the following month, January 7th. The hydrogen lines appear very diffuse and greatly displaced toward the red. A second stronger spectrogram was obtained on January 15th, and the peculiar character of the spectrum can be seen more clearly. The narrow bright low-temperature lines seem to remain unchanged, and measures of their positions indicate no certain variation in the displacements found for them at other phases of the star's light. On the other hand, the hydrogen lines are greatly widened toward the red and show a large displacement relative to the narrow bright lines. The brightest of the three hydrogen lines on the photograph is Hβ, Hγ being next and Hδ faint. They appear short and stubby as compared with the narrow bright lines, which seem to project beyond the continuous spectrum. This last plate is weak and only a few absorption lines are seen:

Two weeks later, on January 29th, another photograph was obtained. The most striking feature on this plate is the presence of the helium line λ4472. It is of moderate strength and, like the hydrogen lines, is broad and diffuse. The hydrogen lines themselves are considerably stronger relative to the continuous spectrum than they were on January 15th, and are cut off sharply at the edge of the continuous spectrum, while the narrow bright lines project beyond. It seems probable that this effect indicates a real difference in the extent of the atmosphere within which the different lines are produced, since the hydrogen lines Hγ and Hβ are brighter than any of the narrow lines, with the possible exception of λ4571, and so should be affected by irradiation at least as much. The helium line λ4472 resembles the hydrogen lines closely in its behavior. It would appear, therefore, that the hydrogen and helium radiations are confined to a low level in the stellar atmosphere, while the narrow low temperature lines extend far out to the higher levels. From the form of the narrow bright lines it seems probable that if such an envelope exists it is somewhat eccentric with reference to the star itself.

A peculiar feature of the spectrum is the presence of what appears to be absorption lines on the violet side of Hγ and Hβ, displaced somewhat to the violet from the normal position of these lines. The combination of bright and dark lines bears some resemblance to that found in P *Cygni* and certain other stars.

A summary of these results may be of interest:

	Hydrogen Lines		Narrow Bright Lines
Date	Character	Displacement	Displacement
1919, December 12	Narrow	+ 51^{km}	+50^{km}
1920, January 15	Broad, diffuse	+140	+55
January 29	Broad, diffuse	+150	+56
February 6	Broad, diffuse	+160	+53

The displacements of the broad hydrogen lines are given in terms of velocity, but it seems more probable that they are due to some cause other than the Doppler effect. The helium line is difficult of measurement, but its displacement seems to be intermediate between that of the hydrogen and the narrow bright lines.

The character of the hydrogen lines and λ4472, and the relative intensities of the former, suggest a source of radiation quite different from that which produced the narrow hydrogen lines seen previously. It is as tho a fresh radiative pulse had occurred in the comparatively dense gas present in the lower layers of the star's atmosphere, thus producing broad lines which, like many of the iron lines investigated in the laboratory, might show a marked widening toward the red.

Especial interest will attach to the observations of the behavior of these lines thruout the star's minimum of light, which will be made as soon as the period admits of work at this phase. At present the conjunction with the Sun occurs during minimum light. The possibility of similar phenomena in the spectra of other stars of type Md near minimum of light is also a matter of much interest.

W. S. Adams.
A. H. Joy.

Photometric Tests of Adams and Joy's List of Stars With Spectra Similar to the Cepheid Variables

In the autumn of 1917 Mr. W. S. Adams kindly forwarded to me a list of stars which because of their spectra might be variables of the Cepheid type. This list was afterwards extended and described by Adams and Joy[1] at the Pasadena meeting of the Astronomical Society of the Pacific. The stars were placed on our observing list for the photo-electric photometer, and while a few measures were made in 1918–1919, it was only during the past few months that opportunity was had to make a test of most of the objects. Each star was compared with one or more comparison stars of nearly the same spectral class, and the measures were usually extended over an interval of three weeks or more. In the table the results are shown by the average deviation of an observation for each star. An observation comprises all the measures taken on one night, usually three sets of four readings each on the suspected variable and comparison stars.

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[1] *Publications A. S. P.*, **31**, 184, 1919.

Boss Number	Star	Harvard Magnitude	Mt. Wilson Spectrum	Average Deviation Magnitude	Number of Observations	Comparison Stars	Remarks
619	14 Persei	5.58	F9	±0.018	3	1	
772	α Persei	1.90	F5	.006	3	2	
1074	58 Persei	4.46	G1	.017	8	1	
1606	ψ^1 Aurigae	5.10	K3	.066	7	2	Variable
1839	δ Canis Majoris	1.98	G1	....	..	..	Too far south
2065	ξ Puppis	3.47	G6	....	..	..	
2153	ρ Puppis	2.88	F6	....	..	..	
4443	β Draconis	2.99	G1	.014	3	1	
4707	45 Draconis	4.95	F8	.009	4	1	
5187	31 o^2 Cygni	3.95	G7	.012	6	2	
5197	α^1 Capricorni	4.55	G1	.006	3	1	
5229	γ Cygni	2.32	F9	.013	5	1	
5255	41 Cygni	4.09	F6	.008	4	1	
5431	ξ Cygni	3.92	K4	.020	3	1	
5676	α Aquarii	3.19	G0	.016	3	1	
5804	5 Lacertae	4.61	K2	.022	3	2	
5931	....	5.48	G0	.008	3	1	
6135	ρ Cassiopeiae	4.85	G5	....	..	..	Irregular variable, Guthnick *A.N.*, **199**, 177, 1914.

It will be seen that only one new variable, ψ^1 *Aurigae*, has been detected. This star has shown a range of more than 0.2 magnitude, but if it has a regular period this can not be less than three months. Probably it is more or less irregular, possibly like the other variable on the list, ρ *Cassiopeiae*. It may be noted that ψ^1 *Aurigae* was the very last star to be tested, and it was not until this, the fourteenth object, was observed that any evidence of real variation was found.

From the residuals for the remaining stars there is found a probable error of one observation equal to ±0.013 magnitude, or for the mean of three observations, ±0.008 magnitude. While this is a greater discordance than would ordinarily occur in this work, it indicates that the stars as a class are fairly constant. In fact, only two or three stars show a measured range as great as 0.06 magnitude, and the others still less. Unless a period is known as in the case of a spectroscopic binary, there is at present no apparent advantage in attempting to follow changes of less than a tenth of a magnitude in irregular or long periods.

Of course it may happen that several other stars of the list are variables which have been missed, and further observations will be made here on suspicious cases. In particular, the three stars which were measured at intervals of a year, 58 *Persei*, 31 *Cygni* and γ *Cygni*, each show a progressive change of 0.02 magnitude during that time, and while no significance is given to this, it may be worth while to follow the stars casually for some time to come.

JOEL STEBBINS.

University of Illinois Observatory,
March, 1920.

THE SPECTRUM OF NOVA LYRAE

The discovery, by Miss Mackie, of a new star in the constellation *Lyra*, was announced in *Harvard College Observatory Bulletin* No. 705. Observations of its spectrum have been secured at the Lick Observatory on the following dates: 1920, February 12, 13, 17, March 4 and 18. They include the region of the spectrum from the ultra-violet to the red at $H\alpha$. There seem to be no emission bands of appreciable strength of shorter wave-length than the limit of the hydrogen series, tho the extreme rays are obliterated by atmospheric absorption at the low altitude at which it was necessary to observe the star in the morning sky.

The principal emission bands are those of hydrogen, the usual compound band near 4650A, a band overlying $H\delta$, which has occurred in many novae, and others in positions 3995, N_2, N_1, 5681, 5752 and 6474A. There are a number of fainter bands whose positions will be given in a more detailed account of the spectrum to appear later. The band 5752 doubtless corresponds with the nebular line 5755A; it was measured on one of the earlier plates, and on all of these N_1* suffers a similar displacement toward the violet with respect to the hydrogen lines which served as the basis of wave-length reductions. The apparent displacement was probably due to a shift of the maximum, such as has been observed in other novae to be peculiar to the bands in question. On March 18 N_1 and N_2 were in their normal positions.

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*N_2 is too faint to record on the early plates.

Generally speaking, the nova may be said to have reached the "nebular stage," tho that term should perhaps be used with reservation for the reason that some of the characteristic nebular radiations, namely 5755 and 6302A, are frequently present early in the development of a temporary star. The nebular band 4363A, which usually becomes strong with the N lines is, in this spectrum, comparatively weak. If it occurs at all it is as a hazy extension, or wing, on the less refrangible side of $H\gamma$. The presence of 4686A is doubtful. There is a narrow maximum in that position, but it would be difficult to interpret it as indicating the radiation in question.

The emission bands are wider on the later plates than on the earlier ones. $H\beta$ increased from a width of about 19A on February 12 to 30A on March 18th.

The nova was of about the 9th magnitude on February 12th, but has since grown somewhat fainter. W. H. WRIGHT.

THE PLANETS IN THE EVENING SKY

Experience has shown that the Moon, to which, in honor of our Bruce Medalist, Professor E. W. Brown, the present number of these PUBLICATIONS is in large part devoted, is always the object of first interest to visitors to the Lick Observatory. One of our telescopes is therefore directed upon the Moon on our public nights[1] whenever it is in good position for observation. It should be said that our satellite is a very disappointing object, telescopically, when at or near the full-moon phase, because there are then no shadows to introduce contrasts. Hence relatively little of the surface detail can be seen satisfactorily. As it is also disappointing when very near the horizon, we are practically limited to the time from about 5 to 10 or 12 days after the new-moon phase.

Next to the Moon, it has been our experience that the three planets, *Jupiter*, *Saturn* and *Mars*, are the objects our visitors most desire to see; and it is the chief purpose of the present note to call attention to the fact that all three of these planets will be favorably placed for evening observation during the next few months. *Jupiter* and *Saturn* both passed opposition with the Sun in February but will be high enough in the sky after sunset for good observation until early July; *Mars* comes to opposition on April 21, and will be well placed for an early evening view from then until September. One or another of these three planets—possibly two when the Moon is not available—will be shown to visitors to the Lick Observatory on public nights during the months named.

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[1] The telescopes are open to visitors reaching the Observatory before 9 P. M. (10 P. M. by summer or daylight-saving time) on every clear Saturday night.

VOLUME XIII, PUBLICATIONS OF THE LICK OBSERVATORY.

Volume XIII, Publications of the Lick Observatory, a brief description of whose contents was given in the February number of these PUBLICATIONS, has now been distributed to the correspondents of the observatory, so far as this distribution is effected by mail. Copies for correspondents in countries served thru the Bureau of Exchange of the Smithsonian Institution left the mountain for Washington at the beginning of April. It should be stated that copies for correspondents in central and eastern European countries are temporarily held in reserve. In conformity with the policy of the University of California, the observatory will be glad to send out these copies as soon as peace has been formally declared with the countries concerned and conditions become more settled.

HONOR FOR DIRECTOR CAMPBELL.

In November, 1919, Albert, King of the Belgians, conferred upon Dr. W. W. Campbell, Director of the Lick Observatory, the rank of Commander of the Order of Leopold II, with insignia.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD IN THE FACULTY CLUB, BERKELEY, CALIFORNIA, ON FRIDAY, MARCH 26, 1920, AT 6:00 P. M.

There were present, President J. H. MOORE, and Directors CAMPBELL, HALE, CUSHING, COSTA, BLACK, AITKEN, BENFIELD, EINARSSON and RICHARDSON.

The Minutes of the previous meeting were approved as printed in the PUBLICATIONS for February, 1920.

The following new members were elected:

W. W. AINSWORTH, of Des Moines, Iowa.
JOHN KOEP, of Chippewa Falls, Wis.
HOWARD J. TURNER, of Vancouver, Wash.
ABEL PEREZ SANCHEZ, of Montevideo, Uruguay.
HOLGAR THIELE, of Lick Observatory.
ROBERT TRUMPLER, of Lick Observatory.
W. H. WRIGHT, of Lick Observatory.
and the
A-B AKADEMISKA BOKHANDLN, of Upsala, Sweden.

Mr. Frank V. Cornish and Mr. J. Costa, active members of the Society, were, on application in due form, elected to Life Membership.

On motion of CUSHING, seconded by CAMPBELL, the salary of the Secretary-Treasurer was fixed at $30 per month, effective from February 1, 1920.

On motion of COSTA, seconded by BENFIELD, all moneys derived from the sale of the Adolfo Stahl Lectures in Astronomy were ordered transferred to the General Fund.

The Treasurer was instructed to draw a check in favor of Professor E. W. Brown, in part payment of his travelling expenses to this coast, in the sum of $150.

On motion of CUSHING, seconded by BLACK, the Finance Committee was authorized to withdraw two Oakland Transit bonds from the custody of the Mercantile Trust Company and deposit them with the re-organization committee now engaged in adjusting the affairs of the Oakland Transit Corporation.

There was some discussion as to the part to be taken by the Astronomical Society of the Pacific in the meeting of the Pacific Division of the A. A. A. of S. at Seattle, in June next, the matter was left to the Program Committee which consists of S. L. BOOTHROYD, of Seattle; R. G. AITKEN, of Lick Observatory; V. M. SLIPHER, of Lowell Observatory, and P. W. Merrill, of the Mount Wilson Observatory.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD ON MARCH 26, 1920, AT 8:15 P. M., IN ROOM 11 OF WHEELER HALL, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIFORNIA.

President J. H. MOORE presided.

The special feature of this meeting was the presentation to Professor Ernest William Brown, of Yale University, of the Bruce Gold Medal of the Astronomical Society of the Pacific. This was the fifteenth award of the medal and Professor Brown came to the Pacific Coast to receive it in person.

The presentation was made in a happily worded address of appreciation by Mr. Beverly L. Hodghead, ex-President of the Society, which called out a gracious response from Professor Brown.

Before proceeding to the formal address of the evening, Professor Brown presented to the Society a copy of his recently published work entitled "Tables of the Motion of the Moon." This copy of Professor Brown's classical and monumental work was forwarded to him from the Cambridge University Press after his departure for the Pacific Coast, and was the first finished copy to reach the author's hands. In presenting it to the Society, with his autograph, Professor Brown has, therefore, placed the Society in possession of a treasure of great historic as well as scientific interest.

The formal address of Professor Brown upon his lunar theory and tables followed and will be found printed elsewhere in this number. It was listened to with profound attention by an audience which was remarkable in its wide representation of astronomical science. There were present delegates from the leading observatories and universities of the coast, and several from points further east.

Brief remarks were made at the close of Professor Brown's address by Directors W. W. Campbell of Lick Observatory and George E. Hale of Mount Wilson Solar Observatory, both highly eulogistic of Professor Brown and his work.

Prior to the presentation and address of the evening, a dinner was given to Professor Brown by the members of the Astronomical Society at the Faculty Club. The following members and distinguished guests were present:

Professor ERNEST W. BROWN, of Yale University.
President DAVID P. BARROWS, of the University of California.
Dr. EDWIN B. FROST, Director of Yerkes Observatory.
Dr. JOHN C. MERRIAM, of the University of California.
Dr. GEORGE E. HALE, Director Mount Wilson Observatory.
Dr. W. W. CAMPBELL, Director of Lick Observatory.
Dr. A. O. LEUSCHNER, Director of the Students Observatory.
Dr. R. G. AITKEN, of Lick Observatory.
Dr. H. D. CURTIS, of Lick Observatory.
Dr. J. H. MOORE, of Lick Observatory.
Dr. W. H. WRIGHT, of Lick Observatory.
Dr. H. THIELE, of Lick Observatory.
Dr. R. TRUMPLER, of Lick Observatory.

Dr. R. T. Crawford, of Students Observatory.
Dr. Sturla Einarsson, of Students Observatory.
Dr. F. H. Seares, of Mount Wilson Observatory.
Dr. T. J. J. See, of Mare Island Naval Observatory.
Dr. S. D. Townley, of Stanford University.
Dr. E. P. Lewis, University of California.
Mr. H. M. Jeffers, of University of California.
Mr. F. C. Leonard, of University of California.
Hon. Warren Olney, of Oakland, Cal.
Mr. Beverly L. Hodghead, of Berkeley, Cal.
Mr. Allen H. Babcock, of Berkeley, Cal.
Mr. John D. Galloway, of Berkeley, Cal.
Mr. L. E. Blochman, of Berkeley, Cal.
Mr. Frank V. Cornish, of Berkeley, Cal.
Mr. Charles S. Cushing, San Francisco, Cal.
Mr. J. C. Cebrian, San Francisco, Cal.
Mr. J. Costa, San Francisco, Cal.
Mr. Fremont Morse, San Francisco, Cal.
Mr. A. L. Black, San Francisco, Cal.
Mr. K. G. Easton, San Francisco, Cal.
Mr. H. H. Sherwood, San Francisco, Cal.
Mr. Bernard Benfield, San Francisco, Cal.
Miss Persis H. Coleman, San Francisco, Cal.
Miss E. W. Allyne, San Francisco, Cal.
Mr. S. I. Allard, Eureka, Cal.
Mr. D. S. Richardson, Berkeley, Cal.
Mr. F. M. Lee, San Francisco, Cal.

OFFICERS OF THE SOCIETY.

J. H. MOORE .... *President*
BERNARD BENFIELD .... *First Vice-President*
J. COSTA .... *Second Vice-President*
A. L. BLACK .... *Third Vice-President*
D. S. RICHARDSON .... *Secretary and Treasurer*
Board of Directors—WM. H. CROCKER, C. S. CUSHING, D. S. RICHARDSON, J. COSTA, R. G. AITKEN, G. E. HALE, B. BENFIELD, W. W. CAMPBELL, A. L. BLACK, J. H. MOORE, STURLA EINARSSON.

Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
Finance Committee—C. S. CUSHING, W. H. CROCKER, A. H. MARKWART.
Library Committee—D. S. RICHARDSON, F. V. CORNISH, BERNARD BENFIELD.
Comet-Medal Committee—W. W. CAMPBELL, STURLA EINARSSON, H. M. JEFFERS.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 128 Lick Building, 35 Montgomery Street, San Francisco, California. Subscription price. $5.00 per year.

PUBLICATIONS OF THE

THE ADOLFO STAHL LECTURES IN ASTRONOMY

This volume contains the twelve Adolfo Stahl Lectures which were delivered in San Francisco in the seasons 1916-17 and 1917-18 under the auspices of the Astronomical Society of the Pacific by members of the staffs of the Lick Observatory, the Mount Wilson Solar Observatory, and the Students Observatory at Berkeley. They cover a wide range of topics, the endeavor being to present in non-technical language, but without sensationalism, some of the more recent results of studies of the Sun, the Moon, the Comets, the Solar System in general, the Stars and the Nebulae. One lecture, also, treats of the methods of astronomical discovery; another of recent progress in the study of motions in the solar system; still another, of the important epochs in the development of astronomy; and the volume concludes with a description of the great 100-Inch Reflector on Mount Wilson, the most powerful telescope in the world.

The volume is well illustrated. There are fifty-four full-page plates and twenty-four figures in the text. Altho the illustrations were selected primarily with reference to the text, they include some which are of historic interest and others which present some of the most recent developments of astronomy. For example, we have Keeler's beautiful drawing of Saturn made on January 7, 1888, the night on which the first successful observations were secured with the 36-inch refractor of the Lick Observatory, and the recent photographs of Jupiter, taken by Slipher at the Lowell Observatory, which are the finest ever made. Some of the stellar and nebular photographs, like the excellent one of the Pleiades by Dr. Isaac Roberts, in 1888, represent pioneer work in this field; others, like Barnard's photograph of the Milky Way in Ophiuchus and the photograph of the Great Nebula in Andromeda showing the location of the Novae recently discovered in it at Mount Wilson are typical of the best work with modern telescopes. On one page we find a photograph of the first reflecting telescope, the historic one-inch invented by Sir Isaac Newton; on other pages, views of the 72-inch reflector at Victoria and the 100-inch reflector at Mount Wilson.

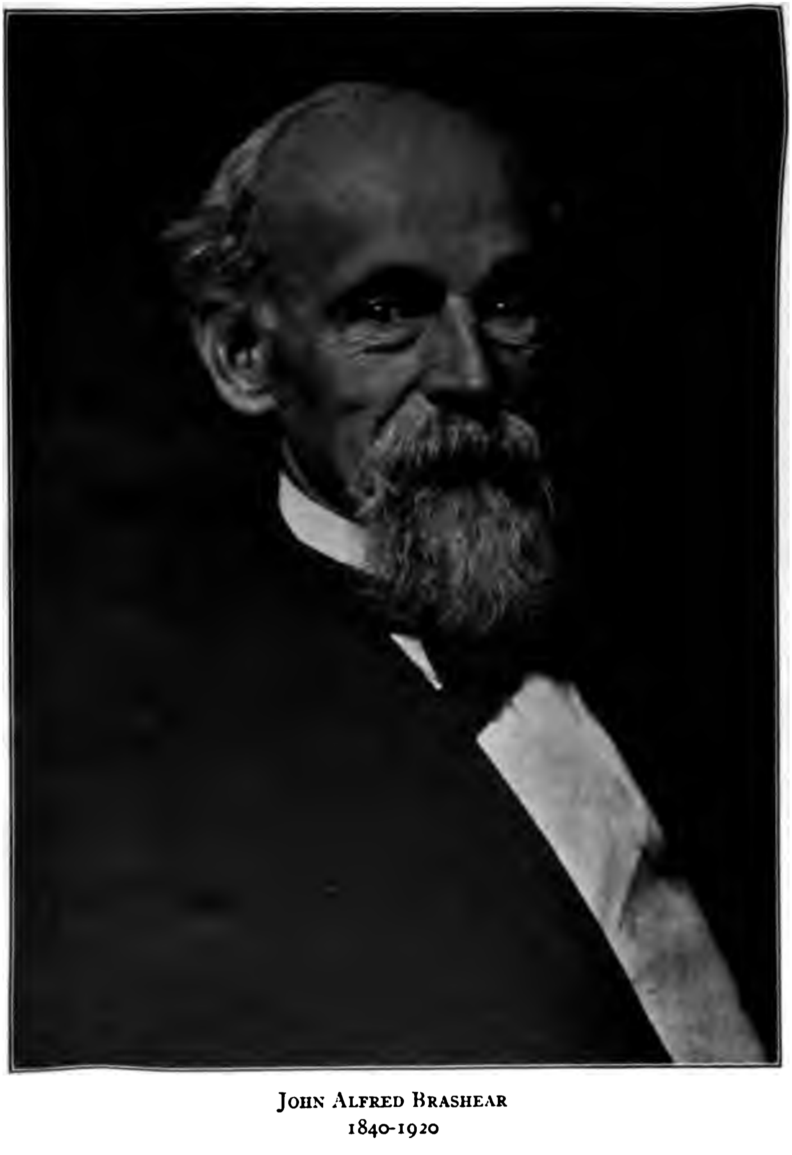
It is, of course, impossible to cover the entire field of astronomical research in a series of twelve lectures; but the topics discussed are representative of modern astronomical work, and the book will introduce the reader to the point of view from which the astronomer of today regards the problems presented to him.

ASTRONOMICAL SOCIETY OF THE PACIFIC

The volume has been printed for the Society at the Stanford University Press and is ready for distribution. The price of the book, substantially bound in cloth, is $2.75, postage paid. Orders should be sent to Mr. D. S. Richardson, 709 Postal Telegraph Building, 22 Battery Street, San Francisco, Cal.

Mr. Stahl has generously provided that the proceeds of the sale of the volume shall go to the Society to form a special fund.

Astronomical Society of the Pacific.



John Alfred Brashear
1840-1920

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

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JOHN ALFRED BRASHEAR

By R. G. Aitken

The death of John A. Brashear on April 8th brought grief to a far wider circle than that of his immediate associates and the friends in his own city; for he had to a most unusual degree the gift for friendship and was loved by all who knew him and held in high regard by thousands more who knew of him only thru his work and his kindly thoughtfulness for his fellow-men. He was the master-maker of lenses and mirrors for great telescopes and of prisms for spectrographs and spectroheliographs; but he was also "Uncle John," the best-loved man in Pittsburgh, and the man named by the governor and the editors of the state in 1915 as Pennsylvania's foremost citizen.

Eloquent testimony to the affection he inspired may be found in the many hundred letters and cards and telegrams which came to him on each recurring birthday anniversary—messages so numerous that it took him several days each year simply to read them all—and in the remarkable birthday party given him in Memorial Hall on November 24, 1915. The vast hall was crowded with his friends, many of them world-famous, many others teachers and workers of Pittsburgh; "a table was heaped high with telegrams of congratulation—from the President of the United States, from men of science all over the world, and some from little blind children whom he had told about the stars." At this dinner a fund of $50,000 was raised, the interest to go to "Uncle John" as long as he lived and after that to be used "to carry on, not to take the place of," the great work he had begun.

His life story has been called a romance—"an inspiration and help to every boy or man who is interested in making the most of himself." Born in Brownsville, Pa., on November 24, 1840, he received a common school education in his native town, in an "ordinary, two-roomed brick building," and at the age of sixteen became an apprentice to a pattern maker in a steamboat building firm of the town. Four years later he went to Louisville, Ky., but after only a short stay there entered a rolling mill at Pittsburgh as a mill-wright. So far the record differs from that of thousands of other boys merely in dates, localities and occupations; the unusual part of John A. Brashear's story lies in the fact that, despite the lack of "opportunities," he was not content to go on doing just ordinary work. His ambition, always, was to do whatever he undertook a little better than it had ever been done before; he had, indeed, many ideals to live for and to realize. As a mere child he had had a look at *Saturn* and at the Moon thru a street telescope, and his grandfather had taught him the names of the brighter stars and of the principal constellations; and even in these early days he had made up his mind that he would one day have his own telescope and know all it was possible to know about the stars.

That is why he studied mathematics and physics and astronomy in the street-cars on his way to and from his work and at night after the close of his hard ten-hour day at the mill; that is why, on Saturday nights, when the mills had quieted down and the smoke had cleared away from the air, he spent long hours studying the stars from the cinder-covered river-bank near his home on the South-side.

On September 25, 1862, he married Phoebe Stewart of Pittsburgh, and found in his wife his chief aide and inspiration in all his plans and work in those early days and thruout her life. Together they literally built their own home, helped in the erection of the framework by friends from the mills, and the little workshop in the rear in which they built their first telescope and ground and figured its 5-inch lens. It took the spare hours of three years to complete this telescope, but not satisfied with it, the young mechanic at once began work upon a 12-inch reflector. The mirror was ready for silvering when it broke in his hands! But encouraged and assisted by his wife, he set to work without delay upon another, which was successful.

Until 1880 Dr. Brashear, to give him the title worthily bestowed upon him by more than one university, continued his work at the mills and his studies at odd hours and his work at night in his own little shop. "In the ash-pit of the mill, men would gather about him at the lunch hour while on strips of sheet iron he chalked suns and moons and comets," and explained the laws that govern their motions. He contributed notes and letters on astronomy to the papers, and Mr. William Thaw, then one of the trustees of the old Allegheny Observatory, is said to have remarked, "Young man, I have learned more astronomy from your letters to the papers than I have from a great many books." This statement is quoted by a writer in the current issue of the *Review of Reviews* with the comment that "this might be pondered by those who deprecate 'newspaper science'." He seems not to realize that if all "newspaper science" were of the order of those letters no one would deprecate it!

It was due to the influence and assistance of Professor Langley and Mr. Thaw that Brashear was able to give up his mill work in 1880 and open an instrument and optical shop of his own near the Allegheny Observatory. The work done here in the forty years since that date has made his name famous wherever optical instruments of precision are used or known. It is not my purpose to enter upon details of this work, for the story is familiar to all who are interested in astronomy. It will suffice to contrast that first lens and mirror, made by a mill-wright in his evening hours with his wife to help him, with such refractors as the 20-inch of the Chabot Observatory and the 30-inch of the new Allegheny Observatory, and with the great 72-inch reflector of the Dominion Astrophysical Observatory, Victoria, B. C.—the second largest in the world—of which, after it has stood the searching test of nearly two years' active use, Dr. Plaskett speaks in terms of highest praise. Always the "apostle of infinite precision," the production of these splendid lenses and mirrors gave him keen satisfaction and it was a matter of special gratification to him that in these later years he was able to produce large mirrors truly plane to the 1/20 of a wave-length of light.

Many honors came to Dr. Brashear in his later years—honorary degrees from great universities, honorary memberships in scientific societies and the recognition, already referred to, as Pennsylvania's most eminent citizen. He served for two and a half years as Acting Chancellor of the Western University of Pennsylvania (now Pittsburgh University), and was President of the American Society of Mechanical Engineers in 1914. It was upon his initiative and chiefly thru his efforts, that the fund of $300,000 was raised with which the new Allegheny Observatory was built and equipped. At its dedication on August 28, 1912, Dr. Brashear referred to his early studies of the stars from the river-bank and said, "I resolved then that whenever an opportunity offered, or if I could make one, I would have a place where all the people who loved the stars could enjoy them." It is to realize this aim that a telescope and a lecture room in the new Allegheny Observatory are specially reserved for the free use of the public.

The honors that came to him sometimes troubled him. He used to say that he lay awake nights wondering what he had done to deserve them; but the title "Uncle John," given him by the teachers of Pittsburgh, by mill-workers, newsboys and the children of the blind asylum, always delighted him. It is characteristic of the confidence and respect Dr. Brashear inspired that a number of years ago he was entrusted by an anonymous friend with a fund of $250,000, placed at his absolute disposal for the benefit of the school teachers of the city. He used the interest of the fund to enable teachers, in their vacations, to travel and attend the Summer Sessions of universities. It is good to know that arrangements have been made to continue this work indefinitely.

On April 2nd, knowing the end was near, Dr. Brashear dictated a three-page document entitled "Directions for my Funeral Services." He asked that his body be incinerated "and afterwards placed in the urn with the ashes of my dear companion who has preceded me to the 'Summer Land.' We both

" 'Loved the stars too fondly
To be fearful of the night.'

"The year of my passing can be cut on the marble tablet that covers the urn in the beautiful crypt under the Keeler dome of the Allegheny Astronomical Observatory."

These directions have been faithfully followed.

I cannot refrain, in closing this tribute to his memory, from quoting also the final passage of this unusual document:

"As my last message to all my dear friends, especially to those who have helped me bear the burdens of others, who by their kindly words of advice, by monetary assistance, have sent a little sunshine into the dark places of earth, who trusted me as a brother, the one who made possible the great work of the educational commission, I leave my tribute of gratitude. To my associates in all my educational work in the University of Pittsburgh, Carnegie Institute of Technology, the Henry C. Frick Educational Commission and its faithful secretary, to my associates in the Astronomical Observatory, who helped make it possible to open it to all; to the School for the Blind, to the Newsboys' Home, to the Phoebe Brashear Club, to all, all, I leave my gratitude and trust that my humble efforts for human uplift will be far surpassed by those of my dear friends who have the religion of humanity in their souls. Such works pay the largest dividends of any investment known to

"Yours faithfully and forever,
"UNCLE JOHN A. BRASHEAR."

REVIEW

PUBLICATIONS OF THE LICK OBSERVATORY, VOLUME XIII, 1918

STUDIES OF THE NEBULAE

By S. I. Bailey

This modest title gives small indication of the amount and variety of the contents of this splendid volume. An outline has already been published by Professor Campbell in the February number of this Journal. The volume is divided into six parts, each of which is worthy of an independent review.

Part I. *Descriptions of 762 Nebulae and Clusters photographed with the Crossley Reflector*, by Heber D. Curtis. The illustrations in this Part, and indeed thruout the volume, add greatly to the value as well as the appearance of the publication.

The study of the nebulae at the Lick Observatory was begun by Keeler, whose early work is so well known thru the Memorial Volume, No. VIII, of the Observatory Publications. The present list of nebulae and clusters includes early as well as late objects obtained with the Crossley Reflector. A careful description of these 762 objects is given, which adds much to our knowledge concerning them. One of the most interesting developments of this study is the information gained concerning the number of the spiral nebulae. On the photographs containing the objects especially sought were found a great number of uncatalogued nebulae, which in many cases were plainly spiral, and, in practically all cases, presumably so. The somewhat arbitrary distribution of the 762 objects might have been expected to give misleading conclusions as to the number of faint nebulae in the whole sky. It has long been known that the small. *white* nebulae avoid the Milky Way, and, as shown so clearly by Wolf in 1902, are massed in great numbers near the north galactic pole. They are much less numerous at the south galactic pole. To the Lick observers is due chiefly the surprising discovery that nearly all these faint objects are spiral nebulae. These spirals seem to bear a definite relation, that of avoidance, to the Milky Way. Keeler estimated the number of such nebulae at 120,000, Perrine at 500,000 and other observers have given different estimates. Dr. Curtis, from a careful consideration of the photographs obtained by himself and his predecessors, and allowing for the unsystematic distribution of the regions examined, places the number which can be reached with the Crossley Reflector at 700,000, possibly 1,000,000. Formerly such figures would have startled us, but there is now no reason to doubt the essential truth of Dr. Curtis' estimate. Incidentally, it is not without interest that among the multitude of these faint nebulae, few, if any, additions have been made to the number of the globular clusters. Several years ago attention was called to the apparent finality of our list of globular clusters. The conclusions of Dr. Curtis appear to confirm the essential accuracy of this statement.

Part II. *A Study of the Occulting Matter in the Spiral Nebulae.* In this Part Dr. Curtis continues his studies of the nebulae. Many details are given in the text, but, to be convinced of the truth of the author's claims, one hardly needs more than to look at the illustrations. A comparison is made between the dark streaks on the spiral nebulae and the dark patches in different parts of the Milky Way, formerly regarded as "holes." In some cases the dark lanes of the spirals have the appearance of partially open spaces between the whorls. In many instances, however, straight absorption bands are seen lying along the axes of the nebulae, apparently viewed on edge. The conclusion seems inevitable that such bands consist of occulting matter intimately associated with the nebulae themselves. Various theories are discussed by the author, but the view that such dark areas, either in the nebulae or in the Milky Way, are vacant spaces is no longer tenable.

Part III. *The Planetary Nebulae.* This Part, also by Dr. Curtis, is an elaborate study of the form and structure of the planetaries. All his investigations are valuable not only for their own worth as scientific studies, but also for the light they throw on the researches which follow relating to the radial velocities and spectra of the gaseous nebulae. Curtis divides the nebulae into three classes: spirals, planetary and diffuse. That the spiral nebulae deserve a class by themselves will not be questioned, this by virtue of their structure, motion and spectrum. The distinction between the planetary and diffuse nebulae seems not so well established. The appearance is distinct, but the character as shown by the spectrum is similar. The number of the planetaries is small, amounting probably to only 150 in the whole sky. That this limit is genuine and not apparent was tested by the author with a slitless spectroscope on 79 small nebulae. Only one of these proved to have a planetary spectrum, all the others having a continuous spectrum. The same fact is shown in the results of the *Henry Draper Catalogue*, which increases the number of classified spectra from 9000 to more than 200,000, with the addition of only one planetary spectrum.

In general the planetary nebulae show a decided preference for the galactic circle, and even the apparent exceptions to this law may be explained as comparatively near objects, really members of the galactic system, altho projected upon other parts of the sky. Such objects are in general larger and hence presumably nearer than the others. The same may be true of the diffuse nebulae. It is of considerable interest that at least four classes of celestial objects, globular clusters, planetaries, diffuse nebulae and Wolf-Rayet stars, are few in number and appear to have a definite limit already approximately attained. All except the globular clusters are found only in the Galactic system or in the Magellanic Clouds. Dr. Curtis has photographed all the planetaries within reach of the Crossley Reflector, 78 in number, using exposures from a few seconds to two hours. Several exposures of varying length were necessary to bring out the different characteristics. When the objects were small and difficult, drawings were made, which incorporate more details than a single photograph could do. The diameters of the planetaries vary from a few seconds to several minutes of arc. One of the most usual and characteristic features is a central star placed within a small and well-defined round or elliptical nebula. The central star, or nucleus, is seldom wanting. The various forms in which these nebulae appear are illustrated with elaborate care. The descriptions and illustrations are followed by a study of the theory of their construction. For the most part they are explained as gaseous spheres, or as ring or ellipsoidal shells. Curtis discusses the place of planetary nebulae in the scheme of stellar evolution. This will be referred to later.

Part IV. *The Spectroscopic Velocities of the Bright-Line Nebulae*, by William W. Campbell and Joseph H. Moore. This paper is the longest in the volume. It would be difficult to exaggerate its importance. Following a résumé of previous investigations along the same line, and a discussion of the instrumental means employed, Director Campbell and Dr. Moore give an elaborate description of their observations and results. These not only deal with the motion of the nebula as a whole, but with differential motion in the nebula itself. The great accuracy of the determinations is indicated by the probable errors. These, for a single observation of the brighter nebulae, amount to only 0.5 km. For fainter objects, when exposures of ten to twenty hours were necessary, and for results obtained in Chile with a less powerful equipment, the probable error is naturally somewhat greater. Such errors are negligible in comparison with the great velocities frequently found. The great nebula in *Orion* was studied in special detail. While its integrated velocity referred to the stars is near zero, the differential motions of closely related areas are conspicuous, amounting to as much as 10 km./sec. Relative motion within the mass of various other nebulae is also indicated by the bent and twisted forms of some of the spectral lines. That they are not rotating as solid bodies is clearly shown by the form of these lines.

The radial velocities of 125 gaseous nebulae were measured at Mount Hamilton and Santiago. From the only bright-line nebula in the Small Magellanic Cloud, a radial velocity of +157 km./sec. was found, when corrected for the solar motion, and this is probably that of the Cloud. From seventeen determinations in the Great Magellanic Cloud a mean radial velocity of +261 km./sec. resulted. These velocities indicate independent systems. The authors give the results of a study of the solar motion as deduced from the planetary nebulae. These results, as might be expected, vary enormously according to the number and grouping of the nebulae employed.

The rotational velocities of a few of the nebulae permitted, with certain assumptions, conclusions regarding their masses. Of three cases given, the masses are 162, 3.7 and 18.8 times that of the Sun. The planetary nebulae in which rotational effects were observed appear to be at least several times as massive as the Sun, but the fainter and apparently smaller planetaries are probably less massive in some cases than the solar system.

The general results are summarized at the end, but are too long for quotation. They are full of interest. In addition to the eighteen bright-line nebulae in the Magellanic Clouds, six of the observed nebulae had velocities greater than +115 km./sec. The average velocity of the thirty-six smaller nebulae, with reference to the stellar system, is 28 km./sec., and that of the other sixty-five objects 31 km./sec. These velocities are about five times that of the Class B stars, a fact having large importance in the theory of stellar evolution. The mean velocity of the five irregular nebulae with reference to the stars is 11 km./sec. The evidence for a Kapteyn preferential motion of these nebulae is slight.

Part V. *The Radial Velocity of the Greater Magellanic Cloud,* by Ralph E. Wilson. This paper gives in detail the determination of the velocity already referred to in Part IV. Some interesting comments are presented on the structure of the Cloud and its resemblance to the Milky Way. The mean radial velocity for the seventeen observed nebulae is doubtless that of the Cloud as a whole, but an attempt was made to verify this by a determination of the velocities of the stars of Class O which are closely associated with it. Unfortunately, the result was inconclusive on account of the faintness of the spectrograms obtained. Previous determinations of the velocities of the bright stars in the region gave a mean velocity of + 6 km./sec., which would be more than accounted for by the recession of the solar system. These bright stars, therefore, are not members of the Cloud but merely projected upon it. Dr. Wilson finds that if 30 *Doradus* is regarded as the nucleus of the Cloud, the northern regions appear to be receding with velocities higher than those near the center, suggesting a rotation about an axis approximately at right angles to the line of sight. The evidence, however, is slight. The author suggests that the Greater Cloud may be a typical spiral nebula, nearer to us than the other spirals.

Part VI. *The Wave-Lengths of the Nebular Lines and General Observations of the Spectra of the Gaseous Nebulae* by William H. Wright. The primary object of this investigation was not discovery but increased accuracy in the determination of the wave-lengths of the known nebular lines. The research was divided into three divisions: 1. The measurements of wave-lengths and the intensities of nebular lines. 2. The study of nebular nuclei. 3. The distribution of nebular radiations thruout the nebulae. The observations are given in detail and are beautifully illustrated by photographs taken with both the slit and the slitless spectrograph. The results depend chiefly upon the measurements of the spectra of nine bright nebulae. Professor Wright has used two scales to represent the relative intensities of the lines, designated Ig and Iq, according as the observation was made with a glass or a quartz prism. Of special interest is Chapter III, in which the relationship between the planetary nebulae and the stars of Class O (Wolf-Rayet stars) is discussed. The distribution of these two groups is similar, as was pointed out long ago by Pickering. A little later Keeler announced his conviction that the nuclei of the planetaries are closely related to the Wolf-Rayet stars. As regards the Harvard classification of these nebulae and stars as Classes P and O, it must be remembered that the work at Harvard has all been done on plates made with the objective prism, and that there is always difficulty in distinguishing between the spectrum of the nucleus and that of the nebulous envelope. Professor Pickering's arrangement of both classes in one group, which he called Fifth Type Stars, appears to be justified in the light of recent knowledge. Wright states that out of thirty nebular nuclei about one-half are Class O stars. The relation, therefore, between the planetary nebulae and Class O stars seems to be well established. Wright suggests the following grouping:

1. Nebulae without nuclei.
2. Nebulae with nuclei. The nuclei are in all instances of very high temperature, and in half the cases show Class O bands.
3. Class O stars, with no (observed) nebulous surroundings. Temperature high.

The author states that the invariable characteristic of the nucleus spectrum is a remarkable extension into the ultra-violet, and would make this fact the dominating peculiarity of the group. The energy curve which this spectrum gives, if interpreted as a heat phenomenon, probably indicates the highest temperature of any stars known. The nebular envelope may be of a much lower temperature. Wright also discusses the relationship of the Novae, whose spectrum is found to correspond rigorously with that of the nebulae.

We have thus an extremely intimate relation between the gaseous nebulae (Class P), the Wolf-Rayet stars (Class O) and the Novae. What place in stellar evolution do they occupy? This question is considered in various places in the volume. Notwithstanding the immense accumulation of data, apparently no final answer can be given. That there is a relation between the spectra of Class O, especially the later divisions, Classes Od and Oe, and Class B was shown by Miss Cannon in 1901, in *H. A.* **28**, 141, when the designation Oe5 was given to spectra which are intermediate. Nevertheless, it would be unsafe to infer that, in general, stellar evolution begins with, or passes thru, Classes P and O to reach Class B and the other classes in the descending series. It has been suggested that the stars of Classes P and O may be the special, rather than the usual, development of giant stars and that the vast majority never attain such high temperatures. The great difference in mean velocity appears to form a barrier between the planetary nebulae and stars of Class B; but, where individual results vary so widely, it may be possible to overestimate the importance of mean results.

In conclusion, it is a pleasure to state that the present volume of the Lick Observatory PUBLICATIONS is a model of its kind. It is filled with exact facts, the results of wisely planned and skilfully executed investigations, together with deductions and theories which are at once moderate and convincing. It goes far toward giving that broad foundation of scientific fact without which any superstructure however glittering is not apt to endure.

Harvard Observatory,
Cambridge, May 5, 1920.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1920

BY MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME

Full Moon	July	1,	12^h41^m A.M.
Last Quarter	"	8,	9 6 P.M.
New Moon	"	15,	12 25 P.M.
First Quarter	"	22,	11 20 A.M.
Full Moon	"	30,	3 19 P.M.
Last Quarter	Aug.	7,	4^h51^m A.M.
New Moon	"	13,	7 44 P.M.
First Quarter	"	21,	2 52 A.M.
Full Moon	"	29,	5 3 A.M.

The Earth is in aphelion July 4th, 4 A. M., Pacific Time.

Mercury is an evening star on July 1st, setting about an hour and one-half after sunset, and therefore in good position for evening observation; but it has already passed greatest elongation and is approaching conjunction with the Sun, so it will be observable for only a few days. Inferior conjunction comes on July 26th, the planet becoming an evening star. It now moves out toward greatest west elongation, $18^\circ 44'$, reaching this on August 14th. It then rises about an hour and one-half before sunrise and is easily visible for a few days; but its distance from the Sun soon begins to diminish rapidly so that by the end of August it has nearly reached superior conjunction. It is in conjunction with *Venus* on July 22nd, with *Neptune* on August 21st and with *Jupiter* on August 31st, but for all three the planets are too near the Sun for easy visibility.

Venus passes superior conjunction with the Sun at noon, July 3rd, Pacific Time, becoming an evening star and remaining such for nearly ten months, or until April 22, 1921. It passes its perihelion on July 21st, but its orbit is so nearly circular that the variation of its motion due to changing distance from the Sun is very slight, a marked contrast in this particular to *Mercury* and *Mars*. After passing conjunction the planet drifts away from the Sun very slowly so that even by the end of August the planet sets only a little more than half an hour after sunset, and will not be an easy naked-eye object even tho it is two magnitudes brighter than *Jupiter*, the next brightest one of the heavenly bodies. It is in conjunction with *Mercury* on July 22nd, with *Neptune* on July 27th, with *Jupiter* on August 8th and with *Saturn* on August 22nd.

Mars is still a rather conspicuous object in the southwestern evening sky altho its apparent distance from the Sun is gradually lessening. On July 1st it sets somewhat after midnight and on August 31st somewhat before 10 P. M. During the two months' period it moves 31° eastward and 10° southward from a position a little east of *Spica*, *a Virginis*, into *Libra*. Its actual distance from the Earth in miles is beginning to grow larger rapidly and increases from 79 million miles on July 1st to 113 millions on August 31st. On July 26th its distance is equal to that of the mean distance of the Earth from the Sun. The increasing distance causes the brightness to diminish more than one-half, but it will still be brighter than all except three or four of the brighter stars at the end of August.

Jupiter is no longer in very good position for evening observation as its apparent distance from the Sun is growing less. It passes conjunction with the Sun on August 21st, becoming a morning star. On July 1st it sets a little more than two hours after sunset; but this interval diminishes to less than one hour before August 1st and disappears entirely at conjunction. It can probably be seen by the naked eye thru the greater part of July, but after August 1st it will not be easily made out.

Jupiter will be in conjunction with *Regulus*, *a Leonis*, just about the same time as it is in conjunction with the Sun.

Saturn is in a little better position, but is rather low down in the evening twilight after July. On July 1st it does not set until about 10:30 P. M., by August 1st it sets before 9 P. M., and on September 1st before 7 P. M. It reaches conjunction with the Sun on September 7th. Both *Jupiter* and *Saturn* are moving eastward and southward in *Leo*, but *Jupiter* is moving about twice as fast as *Saturn*. By the end of August *Jupiter* is about 13° west of *Saturn* and this distance will diminish to about 6° at the close of the year. *Jupiter* will pass *Saturn* during 1921.

Uranus is drawing nearer a favorable position for evening observation. On July 1st it rises about 10:30 P. M. and on August 31st at a little before sunset. It comes to opposition with the Sun on August 26th. It is in the constellation *Aquarius* and moves a little less than 2° westward and 1° southward during the two months. It is in a region of the sky quite barren of bright stars but the planet is not far from the fifth magnitude star *σ Aquarii* during the period, passing from a position 1° east of the star on July 1st to a point 1° west of the star on August 31st. The date of nearest approach is August 7th. The planet will then be about 30′ north of the star, or about the apparent diameter of the Sun or Moon. Under good weather conditions the planet can probably be identified.

Neptune is in conjunction with the Sun on August 3rd.

TITLES AND ABSTRACTS OF PAPERS FOR THE SEATTLE MEETING OF THE SOCIETY

JUNE 17-19, 1920

The Pacific Division of the American Association for the Advancement of Science will hold its annual meeting this year at Seattle, Wash. As one of the affiliated societies, the Astronomical Society will hold a meeting at the same time and place. President J. H. Moore has appointed as program committee S. L. Boothroyd, University of Washington (chairman), R. G. Aitken, Lick Observatory, V. M. Slipher, Lowell Observatory, and P. W. Merrill, Mount Wilson Observatory. The committee has arranged for a meeting on Thursday forenoon, June 17th, at which papers of interest to astronomers and physicists will be presented. The American Physical Society has been invited to meet with us at this time. This Society, in turn, invites us to attend its meeting, to be held on Friday forenoon, June 18th. On Thursday afternoon a Symposium on the subject of Relativity has been arranged, which will be of interest to mathematicians, physicists and astronomers. As will be seen from Dr. Plaskett's letter on another page, an excursion to the Dominion Astrophysical Observatory at Victoria, B. C., has been arranged for Saturday, June 19th. It is expected that a short meeting will be held at the Observatory on Saturday afternoon for the presentation of papers relating to spectroscopic work.

Following is a list of the titles and abstracts of papers so far received. Other papers are known to be in course of preparation. The order here is one of convenience and does not indicate the order in which the papers will be presented.

THE SPECTRUM OF JUPITER

BY V. M. SLIPHER

Improvements during the last few years in dyes for sensitizing dry plates for the lower spectrum made it possible to extend the photographic study of spectra farther into the longer wave-lengths than could be done at the time of my previous investigation of the spectra of the planets. It is intended to give (with illustrations) the results of observations of the spectrum of *Jupiter*, which reveal several new bands and lines due to the selective absorption of the planet's atmosphere.

Photographic Observations of Hubble's Variable Nebula in Monoceros (N.G.C. 2261)

By C. O. Lampland

Brief descriptions are given of some of the changes exhibited in photographs of the nebula taken with the 40-inch Lowell reflector during the past four years. The paper is illustrated by lantern slides.

On a Form of Double-Slide Plate Carrier

By C. O. Lampland

A short description, illustrated by lantern slides, will be given of a form of double-slide plate carrier used with the 40-inch Lowell reflector.

Visual and Photographic Observations of Jupiter, 1919-1920

By E. C. Slipher

Illustrated with slides.

The Spectroscopic Orbit and Dimensions of the Eclipsing Variable U Coronae

By J. S. Plaskett

Altho the photometric orbit of this star indicates that the bright component contains about 85% of the light the spectrum of the fainter is plainly visible indicating the necessity of further photometric work. The brighter star has a diameter of 3.1 and the fainter 4.8 times that of the Sun, while their masses are respectively 4.5 and 1.7 times that of the Sun. The spectrum is very diffuse and difficult to measure but sufficient plates were obtained to give reliable values. The difference between spectroscopic and photometric phases in this star, a quantity which has been found to vary irregularly in other eclipsing variables, is probably not greater than the unavoidable error in the spectroscopic orbit.

Notes on Some Spectroscopic Binaries

By W. E. Harper

The Orbit of the Spectroscopic Binary H. R. 6169

By R. K. Young

THE INTENSITY OF THE HYDROGEN LINES AND THE CONTINUOUS SPECTRUM IN γ CASSIOPEIAE

By H. H. PLASKETT

The intensities are determined on an absolute scale independent of the luminosity curve of the photographic plate by means of a method devised by Merton and Nicholson. The essential features of the method are the use of a neutral tint wedge in front of the slit of the spectrograph and the calibration of the plate by means of the spectrum of the positive crater of the carbon arc. A comparison of the intensity decrement of the Balmer Series under stellar and laboratory conditions is given, and an indication of the use of this method for the determination of stellar temperatures.

THE PRINCIPLE OF GENERAL RELATIVITY

By E. T. BELL

Statement of the principle, the relation to Einstein's work of 1905-12, especially in connection with the field equations of electrodynamics. Invariance of the laws of nature and the Calculus of tensors for the finding of natural invariants. The equivalence hypothesis and gravitational fields. Uniqueness of the part played by gravitation in Einstein's general theory. The manner in which the gravitational field, or the hypothesis regarding it, determines the curvature of space and its particular non-Euclidian nature. The identity of time and space.

The presentation will be with a minimum of mathematics.

THE ASTRONOMICAL BEARING OF THE THEORY OF GENERALIZED RELATIVITY

By CHARLES E. ST. JOHN

The Michelson-Morley experiment.

The motion of the perihelion of *Mercury* and the various attempts to reconcile it with the Newtonian law of gravitation.

The deflection of light in passing thru the near neighborhood of the Sun, as evidenced by the British observations of the eclipse of May, 1919.

The now critical question of the displacement of all solar lines to the red in accordance with the requirements of the Einstein law of gravitation.

THE SPECTROSCOPIC COMMITTEE OF THE DIVISION OF PHYSICAL SCIENCES OF THE RESEARCH COUNCIL

BY CHARLES E. ST. JOHN, Chairman Western Group

An account of the organization of the Research Committees of the Division of Physical Sciences upon the Rockefeller fund.

The formation and membership of the Spectroscopic Committee and its division into Eastern and Western groups.

Plans for stimulating interest and activity in spectroscopic research and for correlating efficiently the activities of the different centers of spectroscopic research.

CONCERNING TABLES OF SOLAR WAVE-LENGTHS IN THE INTERNATIONAL SYSTEM

BY CHARLES E. ST. JOHN AND HAROLD D. BABCOCK

The solar wave-lengths in the Rowland System are compared with iron arc wave-lengths in the International System. It is shown that the lack of homogeneity of the Rowland System is so great that for present-day precision no satisfactory method is available for reducing the present tables of solar wave-lengths to the International System.

The methods of obtaining a homogeneous system of solar standards are discussed and data showing the precision to be expected are given.

A plan for coöperation in the production of the completed tables is outlined.

THREE SPECTROSCOPIC BINARY STARS

BY R. F. SANFORD

The following three stars were announced to be spectroscopic binary stars by Adams and Joy in *A. S. P. Publ.* **31**, 40, 1919. Brief statements are given below concerning the elements derived for their orbits.

O Σ 82 (1920: $\alpha\, 4^h\, 18^m.2$ $\delta +14^\circ\, 52'$ mag. 7.0)

This is a visual binary star which has completed a considerable part of a revolution since first observed. The elements of the visual orbit are still in considerable doubt, the period derived by three different computers ranging from 90 to 158 years. Star A is the spectroscopic binary. Star B, distant $0''.7\pm$, is of 9.0 mag., too faint to produce any effect in the time necessary to photograph the spectrum of A. Only one spectrum shows; its class is F_8, with moderately good lines. The period that best fits the observations is 4.0000 days. This made it possible to get observations for only four sections of the velocity curve but luckily two of these cover the regions of maximum and minimum velocities. The following provisional elements were obtained from 15 spectrograms taken with one-prism dispersion and an 18-inch camera. The observations extend over almost 200 revolutions of the star in its orbit.

P	4.0000 days
e	0.06
ω	$12^\circ.74$
K	36.1 km. per sec.
γ	$+37.4$ km. per sec.
T	J. D. 2,422,274.812
$a \sin i$	1,980,000 km.
$\frac{m^3 \sin^3 i}{(m+m_1)^2}$	$=0.0193\ \odot$

The system is of further interest because its proper motion, radial velocity and position in the sky identify it as a member of the *Taurus* Stream. The importance of a knowledge of the radial velocity and spectral type of star B is realized of course and an attempt will be made to determine them.

205 *Draconis* (1920: $\alpha\ 18^h 45^m.4$ $\delta +49^\circ 21'$ mag. 7.2)

Thirty spectrograms of this star have been obtained. They show that both stars are of Class F_2 and give lines very slightly, if at all, different in intensity. The following elements resulted from corrections to the preliminary elliptical elements by a least squares solution:

P	3.7647 days
e	0.00
K_1	97.7 km.
K_2	98.3 km.
γ	-18.8 km. per sec..
T	J. D. 2,422,159.769
$a_1 \sin i$	5,058,000 km.
$a_2 \sin i$	5,089,000 km.
$m_1 \sin^3 i$	$1.48\ \odot$
$m_2 \sin^3 i$	$1.47\ \odot$

T is the epoch of maximum positive velocity for star one.

These elements give computed velocities for the observational dates that are in as good agreement with the observed velocities as the nature of the spectra would lead one to expect. More than 165 revolutions in the orbit of this star separate the first and last observations of the radial velocity.

Boss 5591 (1920: $\alpha\ 21^h 40^m.8$ $\delta +28^\circ 24'.8$ mag. 6.9)

Nineteen spectrograms of this star have been secured. They show both stars to be of the same spectral class, F_0, and that the lines due to each are of approximately equal intensity. Elements have been derived as follows:

P	3.7486 days
e	0.19
ω	82.66
K_1	93.4 km. per sec.
K_2	92.1 km. per sec.
γ	+4.18 km. per sec.
T	J. D. 2,422,175.158
$a_1 \sin i$	4,728,000 km.
$a_2 \sin i$	4,662,000 km.
$m_1 \sin^3 i$	1.17 $\odot$
$m_2 \sin^3 i$	1.19 $\odot$

The observed velocities, extending over an interval of about 100 orbital revolutions, conform to the computed velocities as well as can be expected from the nature of the spectra and the consequent blending of lines at certain phases.

Relative Wave-Lengths of Skylight and Venus-Reflected Sunlight

By Charles E. St. John and Seth B. Nicholson

Spectrograms of *Venus* have been secured at Mount Wilson Observatory when *Venus* was east of the Sun in 1919 and when west of the Sun in 1919-20. Thirty lines in the region λ 4500 in the *Venus* spectrum have been compared with the same lines in the spectrum of the sky. This comparison shows differences of wave-length that are just at the limit of observation, an average shift of the *Venus* lines of 0.002 angstroms to the violet.

The results are discussed in relation to the altitude of *Venus* and, in view of a possible bearing upon generalized relativity, in relation to the positions of Earth, Sun and *Venus*. The effect of an increasing amount of superposed skylight is also considered.

Radial Velocities and Parallaxes of Additional Stars in the Taurus Group

By Walter S. Adams, Alfred H. Joy, Gustaf Strömberg

Observations of the spectrum of twenty-five stars in the cluster of the *Hyades*, whose proper motions correspond to those of stars belonging to the *Taurus* group, have been made with the 60-inch and 100-inch reflectors. Included among these are the four bright

K-type stars: γ, δ, ϵ and θ' *Tauri*. The results indicate that nineteen of the stars observed belong to the group, while three are doubtful and three do not belong or are spectroscopic binaries with a considerable range of velocity. The mean radial velocity for the nineteen stars is +39 km. and the average parallax computed spectroscopically is +0″.021 with a range of from 0″.013 to 0″.030. The apparent visual magnitudes of these stars vary from 3.6 to 8.7 and thus afford an excellent test of the spectroscopic method. The spectral types of the brighter stars with the exception of the four stars already referred to are considerably less advanced than those of the fainter stars. The parallax of the *Taurus* group as derived by Boss is 0″.025 and that by Kapteyn is 0″.024.

THE SPECTRA OF SOME COMPANIONS TO STARS OF THE B-TYPE

BY WALTER S. ADAMS, ALFRED H. JOY, GUSTAF STRÖMBERG

The spectra of the companions of stars of the B-type are of especial interest because of the wide difference in absolute magnitude shown by such pairs in case they form true physical systems. Observations have been made of the companions of the stars ϵ *Persei*, β *Orionis*, δ *Orionis*, ι *Orionis*, λ *Orionis*, β *Scorpii* and β *Lyrae*. To four of these pairs Burnham assigns a common proper motion, while in the case of the other three the connection is uncertain. The spectrum of the companion is in every case found to be of the B-type, and for all except the companion of β *Orionis* it is of a more advanced type. In the latter case the companion is a close visual binary. The average spectral type of the remaining six brighter stars is B_2 and that of their companions B_6. The average difference in apparent magnitude, is 3.7 magnitudes, which also corresponds to the difference in absolute magnitude in case these stars are physical systems. The difference in the case of ϵ *Persei* is 5.3 magnitudes.

SUMMARY OF SPECTROSCOPIC PARALLAX DETERMINATIONS

BY WALTER S. ADAMS, ALFRED H. JOY, GUSTAV STRÖMBERG

The rapid accumulation of parallaxes determined with a high degree of accuracy by the trigonometric method has made it possible to complete a revision of the standards of reduction used in the spectroscopic method and to derive values which may be considered as subject to but little modification in the future. The revision has been based upon a total number of 657 stars with parallaxes determined by Mitchell, Schlesinger, van Maanen and various observers at the Yerkes Observatory. About 115 of these stars are common to two or more of the observers. The results of the comparison are indicated in the following summary, the differences being taken trigonometric *minus* spectroscopic parallaxes.

	Number	Difference	Mean Deviation
Mitchell......................	194	−0″.0006	0″.0193
Schlesinger....................	287	−0 .0023	0 .0148
van Maanen..................	78	+0 .0036	0 .0110
Yerkes.......................	98	−0 .0032	0 .0210

A very marked improvement would be introduced into these results by the omission of a few stars of very large parallax for which the errors of the spectroscopic values (which are proportional to the amount of parallax) are comparatively large. This is especially true of the M-type stars of very low luminosity. An additional difficulty in the case of these stars is the necessity for observing their spectra with low dispersion on account of their faintness, and this renders the determination of the intensities of the spectral lines less certain. The omission of four such stars, for example, from the Yerkes list would reduce the difference to −0″.001. The difference in the case of van Maanen is also due in large measure to a very low discordant value.

The agreement of the individual parallaxes derived by the two methods compares very favorably with that found by different observers using the trigonometric method alone; and the small value of the systematic difference from these four excellent series of trigonometric values appears to justify fully the adoption of this system in the reduction of the spectra of about 1700 stars for which data are now available.

Parallax Notes

By Adrian van Maanen

Miscellaneous Items Relating to the Spectra of Long-Period Variable Stars

By Paul W. Merrill

1. A summary of the radial velocity data for about eighty-five stars.
2. The presence of low temperature lines in the absorption spectra.
3. R *Andromedae* and similar stars.
4. R *Aquarii.*

THE FORM OF THE GREEN NEBULAR BANDS IN NOVA AQUILAE III

BY J. H. MOORE

The peculiar forms of the N_1 and N_2 nebular bands obtained when the slit of the spectrograph was placed in different directions across the small greenish disk of *Nova Aquilae* III, will be shown (with slides). A discussion of possible interpretations of the observations will be given.

OBSERVED CORRECTIONS TO THE RIGHT ASCENSIONS OF THE PRELIMINARY GENERAL CATALOG OF BOSS

BY R. H. TUCKER

Observations made at the Lick Observatory in the years 1906-1908. Two hundred and fifty-five stars from +38° and −38° declination. Eight observations each, both positions of the instrument, fixed circle east and fixed circle west. *Polaris* observed at both culminations with each night, fifty nights. Systematic corrections with respect to declination only.

THE METEOR CRATER, ARIZONA

BY W. W. CAMPBELL

In Central Arizona, twenty miles west of Winslow and six miles south of the Santa Fe railway, is a remarkable hole in the ground, circular in form, about 4200 feet in diameter, its bottom about 400 feet lower than the general level of the surrounding plains. The rim of the hole is from 130 to 160 feet higher than the surrounding plains, and the surface outside of the rim slopes down, in from one-quarter to half a mile, to the general level. Thousands of iron meteorites, varying from individuals weighing several hundred pounds down to grains of minute weight, have been found in all directions from this hole and a few within the hole. The general form of the hole and its rim resembles that of the lunar craters comparable in size with it. The Arizona crater has been studied by geologists but not by astronomers. Geologists are divided in opinion as to its origin: some favor the hypothesis of origin by internal explosion, such as by steam under high pressure, others advocate an origin by meteoric impact. The present paper discusses the merits of these hypotheses, and provisionally favors the meteoric origin. Twenty minutes, with lantern slides.

PRELIMINARY ORBITS OF FOUR BINARY STARS

BY R. G. AITKEN

The stars are β 552, Σ 412, β 1185, OΣ 341. The observed motion in the first two extends over considerably less than one revolution but the elements now derived, while preliminary, are regarded as fair approximations. These two orbits are of average eccentricity and inclination to the plane of projection.

The other two orbits are alike in being highly inclined to the plane of projection but present a marked contrast in the eccentricity, one being rounder than the orbit of *Mercury*, the other ranking with that of ζ *Boötis*, the double-star orbit having the largest eccentricity heretofore known. The periods of these two systems are accurately determined and the major axes are also fairly determinate. Unless the masses are much greater than the average, it follows from the orbit data that both stars have measurable parallaxes.

OBSERVATIONS OF THE SPECTRUM OF OMICRON CETI IN 1919

BY C. D. SHANE

COMET *c* 1915 (TAYLOR)

BY H. M. JEFFERS

NOTES FROM PACIFIC COAST OBSERVATORIES[1]

NOTES ON THE BINARY STAR SIRIUS

Many interesting and useful speculations rest vitally upon the assumption that two stars of the same spectral type are equally efficient as radiators of light. This is equivalent to saying that two stars of the same spectral type have absolute brightnesses proportional to their surface areas. There is apparently much justification for the use of this principle in discussing the attributes of stars, for stellar spectra are undoubtedly surface phenomena, and spectral types are probably quite definite functions of effective surface temperatures.

This assumption is chiefly responsible for the conclusion reached by one astronomer, that the diameter of a Cepheid variable star of seven-day period may be estimated at twenty-six times the Sun's diameter. A further direct result is that such a Cepheid is 2.7 times as massive as the Sun, but only 1/7000th part as dense as the Sun. From this assumption and its conclusions come seemingly fatal difficulties for the binary hypothesis of Cepheid variables. I am not here defending this hypothesis, but it is undoubtedly of some interest to apply the assumption to the binary star *Sirius*, concerning which we know many facts.

The primary component of *Sirius* is about ten magnitudes brighter than the secondary component; that is, it radiates 10,000 times as much light. Adams, with the 60-inch reflector of the Mount Wilson Observatory, has observed that the spectra of the two components are identical in character, save that the continuous spectrum of the companion seems to decrease a little more rapidly than that of the principal component, as one proceeds toward the ultra-violet. Van Maanen, photographing *Sirius* thru color screens with the same telescope, has given general confirmation to Adams's result, by showing that the two components of the binary have essentially the same color index. Adopting the assumption of direct relationship between spectral class and radiating efficiency, we have the surface area of the principal component 10,000 times as great as that of the secondary. The radii of the two stars are therefore as 100 to 1, and the volumes are as 1,000,000 to 1. Now it is well established that the mass of the fainter component is essentially equal to that of our Sun, whereas the mass of the principal component is twice that of the Sun. It therefore follows that the secondary star is 500,000 times as dense as the primary. This is a most surprising result. Are we justified in assigning to it even a fair degree of probability?

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[1] See also Titles and Abstracts of Papers for the Seattle Meeting of the Society, June 17-19, on page 189

As to luminosity and diameter, the principal star is a giant and the secondary star is at least relatively a dwarf; but as to mass they are average stars. Have we any reason to doubt that in years the two stars composing the system of *Sirius* are identically of the same age? Their spectra are of Class A. What has been their evolutionary history to date? Did they begin their stellar lives as Class B stars, and have they traveled along parallel courses of development to Class A stars? Following another hypothesis, did they begin their stellar lives as Class M stars? Have their evolutionary processes travelled along parallel lines and with equal speeds to the Class A stage, where we now find them, or has the giant primary star traveled in one direction from Class M to Class A, whereas the dwarf companion has traveled from Class M in one direction to Class B, and thence in the reverse direction to Class A? If we grant that the primary star is only 1/500,000 as dense as the secondary, which the assumption outlined at the beginning of this note absolutely requires, either one of the evolutionary progressions which begins with Class M involves an extreme of improbability.

Is the assumption of direct relationship between spectral type and radiating efficiency a reliable one? The purpose of this note is merely to raise the question. W. W. CAMPBELL.

NOTE ON THE Hα LINE IN THE SPECTRUM OF T PYXIDIS

Photographs with the 10-inch Cooke telescope and a 15° objective prism made on April 21, 22, 23, 24, 25 and 26, 1920, have shown a very strong bright Hα line in the spectrum of T *Pyxidis*. The line stands out strongly by itself, being so bright that intense images were obtained in thirty minutes' exposure time. In spite of the low dispersion (approximately 440 angstroms per millimeter at Hα) the continuous spectrum in the red is very weak. Seed 23 plates stained with pinacyanol were used.

In the ultra-violet the dark components of the hydrogen lines are much stronger relative to the bright components than at Hβ and Hγ.

May 6, 1920. MILTON L. HUMASON.

LETTER FROM PROFESSOR PLASKETT

DEPARTMENT OF THE INTERIOR
DOMINION ASTROPHYSICAL OBSERVATORY

Victoria, B. C., April 21, 1920.

Prof. J. H. Moore,
President Astronomical Society of Pacific,
Lick Observatory,
Mt. Hamilton, Cal.

Dear Professor Moore:—

As you no doubt know an excursion is being arranged to this observatory as part of the programme of the meeting of the Pacific Coast Section of the American Association and of the Astronomical Society of the Pacific at Seattle in June.

I beg to extend through you a hearty invitation to all members of the Society to visit the observatory at this particular time or at any other time that may be convenient to them. We are always glad to see those interested in astronomy at the Observatory and I can assure them of a cordial welcome and an opportunity to see the work of the Observatory.

Yours sincerely,
J. S. PLASKETT, *Director.*

RESIGNATION OF DR. CURTIS

I regret to announce that Dr. Heber Doust Curtis, Astronomer in the Lick Observatory, has resigned to accept appointment as Director of the Allegheny Observatory of the University of Pittsburgh. The change of position will occur on July 1st. I desire at the same time to congratulate the Allegheny Observatory upon obtaining a director so well fitted by personality and scientific qualities to serve in succession to Langley, Keeler, Wadsworth and Schlesinger. The astronomers and all the members of the Mount Hamilton community are reconciled with difficulty to the departure of Dr. Curtis and his family. They have fitted most admirably into the scientific and social life of the mountain, and their loss will be seriously felt.

Dr. Curtis, born in Detroit, Michigan, is a graduate of the University of Michigan, where his chief subjects of interest were the classic languages. In the middle '90's he was Professor of Latin and Greek in Napa College, California, and in the late '90's he was

Professor of Mathematics in the College of the Pacific, San Jose. In the year 1900 he decided, perhaps to some extent influenced by his residence in the shadow of the Lick Observatory, to change his subject to astronomy. With great courage on the part of himself and Mrs. Curtis, he resigned a professorship to accept appointment as Fellow in Astronomy in the University of Virginia, with salary at the rate of $350 per annum, where the family of four resided in the years 1900-02. Receiving the doctor's degree in June, 1902, Dr. Curtis served as an assistant in the Lick Observatory from 1902 to 1906. He was Acting Astronomer in Charge of the D. O. Mills Observatory at Santiago, Chile, from February, 1906, to June, 1909. From the latter date to the present he has filled the position of Astronomer in the Lick Observatory, as successor to Dr. Perrine, who became Director of the National Observatory of the Argentine Republic at Cordoba.

W. W. Campbell.

Degrees Awarded

At the recent Commencement of the University of California May 12, 1920, the degree of Doctor of Philosophy was conferred upon two students having Astronomy for their major study—Miss Sophia H. Levy and Mr. C. D. Shane. Miss Levy's thesis was entitled "The Theory of the Motion of the Planet (175) *Andromache*," and Mr. Shane's "The Spectra of Certain Class N Stars."

GENERAL NOTES

The Centenary of the Royal Astronomical Society.—The one hundredth annual meeting of the Royal Astronomical Society of London, which was held on February 13, 1920, is an event worthy of more than passing notice. "A fitting celebration of this event," said Professor Alfred Fowler in his presidential address, "has been rendered impossible for the present by circumstances arising out of the war, but the question has become the subject of consideration by the Council, and their proposals will be announced in due course."

In his address[1] Professor Fowler gives an interesting account of the founding of the Society and of its early history. It appears that the honor of being the founder belongs to the Rev. Dr. William Pearson, an excellent observer and the author of *An Introduction to Practical Astronomy*, which is still full of interest to the student of astronomy. But the claims to this honor of Francis Bailey, whose name is now best known in connection with the phenomenon of "Bailey's Beads," are only second to those of Dr. Pearson, and Bailey was even more active in organizing the work of the Society. In the list of the fourteen signers of the original agreement drawn up at the meeting held on January 12, 1820, to consider the question of establishing such a society, we find the names of Stephen Groombridge, J. F. W. Herschel and James South; and Sir William Herschel, then eighty-two years of age, became in 1821 the first President of the Society.[2] We refer our readers to Professor Fowler's very interesting address for further details of the early history of the oldest, and, in may respects, the most important astronomical society in the world.

In its first century the Society has exercised a powerful influence upon the development of astronomy. Its two series of publications, the *Memoirs* and the *Monthly Notices*, are indispensable to the astronomer; its associates and medalists have been chosen so judiciously that such recognition is a stimulus as well as a high honor. Further, the discussions at the regular meetings, as printed in the *Observatory*, are followed with the keenest interest by astronomers everywhere. It is a matter for congratulation that the Society enters upon the second century of its history with prospects of even greater usefulness. It has a total membership of 767 (including fifty Associates in foreign countries), a permanent and beautiful home in Burlington House, a splendid library and ample financial resources.

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[1] Printed in the February, 1920, number of the *Monthly Notices*, copies of which have just reached Mt. Hamilton.

[2] There was no president for the first year.

The Henry Draper Catalogue.—Volume 94 of the *Annals of the Harvard College Observatory* contains the fourth instalment of the great *Henry Draper Catalogue*, including the stars in 9, 10 and 11 hours of right ascension. The four volumes of the catalog which have now been issued make available to astronomers the spectral class of 104,953 stars in the half of the sky from 0.0 to 12.0 hours right ascension.

Photographs of representative stellar spectra and portraits of Dr. and Mrs. Henry Draper were presented as the frontispieces of the first three volumes. It is fitting, as Professor Bailey says, that the frontispiece of the present volume should be the portrait of the late E. C. Pickering, under whose direction the work was undertaken and brought practically to completion, but who lived to see only the first three volumes in print.

Publications of the Dominion Astrophysical Observatory.—In Volume I, No. 1, of the *Publications of the Dominion Astrophysical Observatory*, Victoria, B. C., which has just been issued, the Director, Dr. J. S. Plaskett, gives a detailed account of the great 72-inch reflector and of the observatory building.[1]

Observing work with the great telescope began on May 7, 1918, and has since been carried on with enthusiasm and marked success by the director and his limited staff. The performance of the instrument under actual working conditions has surpassed even the sanguine expectations of Dr. Plaskett, and he is led to conclude that "this instrument in optical and mechanical perfection, in convenience and speed of operating is, in my opinion, unequalled in the world."

Seven additional parts of this volume, giving some of the results of the first year's work, are in press and are soon to be issued.

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[1] For an excellent brief account see Dr. Plaskett's article in the October, 1918, number of these PUBLICATIONS.

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Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 128 Lick Building, 35 Montgomery Street, San Francisco, California. Subscription price, $5.00 per year.

PUBLICATIONS OF THE

THE ADOLFO STAHL LECTURES IN ASTRONOMY

This volume contains the twelve Adolfo Stahl Lectures which were delivered in San Francisco in the seasons 1916-17 and 1917-18 under the auspices of the Astronomical Society of the Pacific by members of the staffs of the Lick Observatory, the Mount Wilson Solar Observatory, and the Students Observatory at Berkeley. They cover a wide range of topics, the endeavor being to present in non-technical language, but without sensationalism, some of the more recent results of studies of the Sun, the Moon, the Comets, the Solar System in general, the Stars and the Nebulae. One lecture, also, treats of the methods of astronomical discovery; another of recent progress in the study of motions in the solar system; still another, of the important epochs in the development of astronomy; and the volume concludes with a description of the great 100-inch Reflector on Mount Wilson, the most powerful telescope in the world.

The volume is well illustrated. There are fifty-four full-page plates and twenty-four figures in the text. Altho the illustrations were selected primarily with reference to the text, they include some which are of historic interest and others which present some of the most recent developments of astronomy. For example, we have Keeler's beautiful drawing of Saturn made on January 7, 1888, the night on which the first successful observations were secured with the 36-inch refractor of the Lick Observatory, and the recent photographs of Jupiter, taken by Slipher at the Lowell Observatory, which are the finest ever made. Some of the stellar and nebular photographs, like the excellent one of the Pleiades by Dr. Isaac Roberts, in 1888, represent pioneer work in this field; others, like Barnard's photograph of the Milky Way in Ophiuchus and the photograph of the Great Nebula in Andromeda showing the location of the Novae recently discovered in it at Mount Wilson are typical of the best work with modern telescopes. On one page we find a photograph of the first reflecting telescope, the historic one-inch invented by Sir Isaac Newton; on other pages, views of the 72-inch reflector at Victoria and the 100-inch reflector at Mount Wilson.

It is, of course, impossible to cover the entire field of astronomical research in a series of twelve lectures; but the topics discussed are representative of modern astronomical work, and the book will introduce the reader to the point of view from which the astronomer of today regards the problems presented to him.

ASTRONOMICAL SOCIETY OF THE PACIFIC

The volume has been printed for the Society at the Stanford University Press and is ready for distribution. The price of the book, substantially bound in cloth, is $2.75, postage paid. Orders should be sent to Mr. D. S. Richardson, 709 Postal Telegraph Building, 22 Battery Street, San Francisco, Cal.

Mr. Stahl has generously provided that the proceeds of the sale of the volume shall go to the Society to form a special fund.

ASTRONOMICAL SOCIETY OF THE PACIFIC.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXXII. San Francisco, California, August, 1920 No. 188

ON CHANGES IN THE CORONA OF JUNE 8, 1918

BY JOHN A. MILLER

The corona of June 8, 1918, presented several striking features but no other one that occasioned more comment than the series of arches of coronal material that surrounded each of various eruptive prominences; and justly so, because they are unusual phenomena and because they were more numerous, better defined and more conspicuous than those occurring in any other of the recent coronas.[1]

These arches are bright coronal streams about as broad as the average polar ray. The stream issues from the margin of the Sun; and its course in the beginning is sensibly radial, but at a slight distance from the Sun the stream begins to curve toward the prominence, finally meeting immediately above it another similar and similarly placed streamer which comes up from the opposite side of the prominence. These two streamers form an ogival arch strongly resembling a Gothic arch. This bright arch is usually enveloped by another larger one similar in shape and separated from it by a dark space. This one in turn is enveloped by a third and in some instances the third one by a fourth. The arches extending highest seem more ogival (more pointed) than those which they envelop and in some instances the arch nearest the prominence seems to be a continuous stream which issues from the Sun on one side of the prominence, passes over it to the Sun on the opposite side of the prominence. Even in these cases the stream seems thinner and less bright immediately above the prominence than at the bases, and in general the arches are brighter near the edge of the Sun than at even a small distance from it.

It seemed possible that changes in this or other coronal structure might be detected by comparing plates made at two stations separated as far as possible in longitude. The present paper is concerned with a study that we made for this purpose.

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[1] See, however, a discussion by Perrine, *Publ. A. S. P.*, **13**, 196, 1901

Three sets of plates were used in the study.

1. Director Campbell of Lick Observatory most generously put at my disposal a glass positive of a photograph made by the Crocker Eclipse Expedition from the Lick Observatory located at Goldendale, Washington (Long. $8^h3^m21^s.5$. Lat. $45°48'.9$.). The Lick plate was made with a camera whose focal length is approximately 40 feet. Totality at Goldendale lasted for about one minute and fifty-seven seconds. The plate loaned me by Director Campbell was exposed from one minute and fifty seconds to one minute and fifty-two seconds after the beginning of totality.

2. We also had a glass positive, loaned me by Director Slipher of Lowell Observatory, from a photograph made by the Lowell Observatory Eclipse Expedition which was located at Syracuse, Kansas (Long. $6^h46^m52^s$. Lat. $38°5'.3$.). This plate was made with a camera of 38.7 feet focal length and was exposed from ½ to 4th second of totality.

3. Glass positives made from negatives made by the Eclipse Expedition from Sproul Observatory. The Sproul Station was located at Brandon, Colorado (Long. $6^h49^m49^s$. Lat. $38°27'36''$). Brandon is about seventy-five miles from Syracuse and west of it. The Sproul plates were made with a camera of focal length sixty-two and a half feet. Two Sproul negatives were used. One was exposed for two seconds at the beginning of totality and the other for three seconds at the end of totality. For reasons pointed out later a series of five positives which varied considerably in photographic density were made from the last named negative.

The time of mid-totality at Goldendale was roughly twenty-six minutes earlier than that at Brandon.

Miss Margaret E. Powell, a graduate student at Swarthmore College, and I made a study of these plates. We hoped, in the beginning, to be able to identify nuclei or other distinctive features on the various plates, and to establish change of structure, or lack of it, by measuring their positions on the plate. The structure, however, was too non-committal to draw conclusions in this way. We finally decided to confine our attention to the arches, and Miss Powell measured three of them in the following manner. She found geometrically the center of the Moon's image. Having computed the displacement of the center of the Sun relative to that of the Moon for each plate, the position of the center of the Sun was plotted on the plates. A point, which could be certainly identified on each plate was selected. Choosing a line thru this point and the center of the Sun as initial line, and the center of the Sun as the origin, any point could be located by its polar coördinates, ρ, θ. The polar coördinates of a series of points lying along the middle of the stream forming an arch were measured on the Lick plate. The same series of vectorial angles were set off on the Sproul plates and the corresponding radii vectores measured. The Lowell plate was treated in the same way.

Since the vectorial angles are the same it is evident that if the corresponding radii vectores are the same the arch is not sensibly changed, but that if they are different (assuming the measures are exact) either the shape or the position of the arch has changed in the twenty-six minutes, which elapsed between the exposures.

We chose for measurement three arches. The first is an arch around the Pyramid Prominence which is about 27° north of the east extremity of the Sun's equatorial diameter. Toward the pole side of this prominence there are four well defined arches; the second of these arches counting from the prominence, was measured.

The second arch measured was around the Southeastern Prominence which is about 88° south of the east end of the Sun's equatorial diameter. There are four well-defined arches on the equator side of the prominence, the inner one of which was measured.

The third is around the Skeleton Prominence which is 8° south of the west end of the Sun's equatorial diameter. This prominence has four distinct arches on the equator side, the fourth of which, counting outward, was measured. The arches on the pole side were much less distinct, due, we supposed, to the presence of another prominence beyond the edge of the Sun.

It will be noted that these prominences are well distributed around the circumference of the Sun, and that an error in plotting either the center of the Sun or of the Moon will affect the measures of different arches in different ways. All linear distances on the Lick plate are reduced mathematically to the scale of the Sproul plate by multiplying the quantity measured (on the Sproul plate) by $1.004 \times \frac{D_3}{D_1}$, where D_3 and D_1, are the linear diameters of the Moon measured respectively on the Sproul and the Lick plates. The factor 1.004 is computed from the hour angle, the zenith distance of the Moon and its distance from the center of the Earth at the time of totality at the two stations. For example, any measured radius vector measured on the Lick plate is reduced to the scale of the Sproul plate by multiplying it by $1.004 \times \frac{D_3}{D_1}$. In what follows θ denotes the vectorial angles; ρ_1 and ρ_2 are the measures of the radius vectors on the Lick and Lowell plates respectively thus reduced to the scale of the Sproul plate; and ρ_3 the corresponding radius vectors measured on the Sproul plates.

There are three sets of measures. The first set was made with the center of the Moon as origin. The quantity ρ was measured from this point. After the measures indicated that the arches had changed we computed the values of ρ_1 and ρ_3 that would have been obtained had we used the center of the Sun as origin. There were four sets of these measures which we averaged and called Series I. These measures were made on the Lick and Sproul plates only.

About three months later we plotted the actual center of the Sun on each plate and measured the arches on the Lick and Sproul plates again. The vectorial angles are measured from the same point but it was impracticable to set off the same vectorial angles as had been set off before. We called this set Series II.

Two questions arose. The first was whether we should compare plates made with cameras differing so much in focal length. The second was whether or not the difference in the values of the ρ's might not be different because the plates had not had equivalent exposure time.

To answer the first question we measured a Lowell plate. It is evident that because of the proximity of the Sproul and Lowell stations that the values ρ_3-ρ_2 should approximate zero, and that the sum of the differences should be a very small negative quantity; and this is what happens. (See Table I, Series III, and Table II, Series III.) There is a somewhat large discrepancy in the first measure of each of the Lowell and Sproul series because this point was very near the edge of the Sun and the measures were somewhat uncertain.

To answer the second question as nearly as possible we printed with different degrees of density five positives from one of the Sproul plates. We measured two of the arches, on the Lowell plate and on each of these positives of the Sproul plate, using the same set of vectorial angles thruout that was used in Series II.

The values of the Sproul plate given in Series III is the average of the measures made on the series of five positives just referred to.

TABLE I

ARCH ABOVE THE PYRAMID PROMINENCE

Series I

ρ_3 (Sproul)	ρ_1 (Lick)	ρ_3-ρ_1 (Sp-Li)	Θ
4.09	4.10	−0.01	6°06′
.29	.24	+ .05	4 54
.38	.28	.10	4 18
.44	.32	.12	3 30
.46	.38	.08	2 36
.51	.42	.09	2 12
.52	.44	.08	1 36

Series II

ρ_3 (Sproul)	ρ_1 (Lick)	ρ_3-ρ_1 (Sp-Li)	Θ
4.00	3.90	+0.10	7°28′
.14	.98	.16	6 40
.28	4.20	.08	5 33
.31	.24	.07	5 08
.48	.36	.12	3 50
.53	.45	.08	2 46
.56	.49	.07	2 22

Series III

ρ_3 (Sproul)	ρ_2 (Lowell)	ρ_3-ρ_2 (Sp-Lo)
3.96	4.02	−0.06
4.12	.17	.05
.26	.27	.01
.32	.32	.00
.44	.42	+ .02
.51	.52	− .01
.54	.52	+ .02

TABLE II

THE ARCH ABOVE THE SOUTHEASTERN PROMINENCE

Series I

ρ_3 (Sproul)	ρ_1 (Lick)	ρ_3-ρ_1 (Sp-Li)	Θ
3.87	3.80	+0.07	+1°48′
.94	.82	.12	1 18
.97	.87	.10	0 48
4.00	.93	.07	0 24
.02	.96	.06	−0 18
.03	.96	.07	0 30

Series II

ρ_3 (Sproul)	ρ_1 (Lick)	ρ_3-ρ_1 (Sp-Li)	Θ
3.84	3.69	+0.15	+1°45′
.91	.77	.14	1 15
.97	.86	.11	0 00
4.03	.90	.13	−1 [illegible]

Series III

ρ_3 (Sproul)	ρ_2 (Lowell)	ρ_3-ρ_2 (Sp-Li)
3.83	....	......
.90	3.87	+0.03
.95	.97	− .02
4.00	4.02	− .02

TABLE III

The Arch Above the Skeleton Prominence

Series I				Series II			
ρ_2 (Sproul)	ρ_1 (Lick)	$\rho_2-\rho_1$	θ	ρ_2 (Sproul)	ρ_1 (Lick)	$\rho_2-\rho_1$	θ
4.13	4.01	+0.12	20°31′	4.03	3.77	+0.26	18°20′
.20	.10	.10	21 24	.16	.86	.30	20 00
.25	.18	.07	22 30	.22	.98	.24	21 30
.30	.22	.08	24 06	.25	4.11	.14	23 37
.32	.28	.04	24 42	.28	.20	.08	25 10
.36	.31	.05	25 42	.38	.24	.14	26 40
.41	.33	.08	27 00	.38	.28	.10	28 13
.44	.36	.08	28 06				
.47	.41	.06	28 48				
.50	.42	.08	29 48				

TABLE IV

Southeastern Prominence

	1	2	3	4	5	Average
1........ −1 25′	4.00	4.00	4.00	4.00	4.00	4.00
2........ 0	3.94	3.96	3.94	3.97	3.94	3.95
3........ 1 15′	3.91	3.91	3.84	3.91	3.88	3.90
4........ 1 45′	3.84	3.84	3.81	3.81	3.84	3.83

They, as well as the Lowell measures, may be compared directly with Series II.

In Table IV I have given the measures of these five positives from the Sproul plate. The positives were of very different density varying from one just as weak as could possibly be made, and yet show the arches, to one as dense as could be made without entirely obliterating the arches. Yet no systematic differences are revealed in the measures. The results for one of the arches is shown in Table IV. The quantity ρ is measured in inches.

In interpreting these results one must not be unmindful of the difficulties of these measures and the consequent uncertainty. I want to consider briefly possible sources of error.

1 The measures themselves: The streamers from their nature are somewhat indefinite, tho the photographs were very good. The measures were very conscientiously made. No one could have been more painstaking than Miss Powell has been. Series I was made three months before Series II and eight months before Series III, so that no prejudice could have been carried into the measures. Any two series are reasonably consistent and the last two remark-

ably so, and in one thing absolutely so—the quantity $\rho_3-\rho_1$ is always positive. These tables were made up by averaging a series of individual measures. There were 156 individual measures. Eight of these gave negative $\rho_3-\rho_1$. Moreover, the ρ's measured on the two Sproul plates, one made at the beginning, the other at the end of totality, are remarkably accordant.

2. An error in plotting the center of the Sun will change the values $\rho_3-\rho_1$. However, if one will make a drawing of the Sun and the three arches that were measured (for location of arches see page 209) he will find that the distribution of the arches is such that an error which decreases any given set of $\rho_3-\rho_1$, will increase one or both of the remaining two sets. That is, one cannot choose an origin that will make all of these differences disappear. Moreover, the center of the Sun was determined four times on each of the plates and measures of the arches made after each determination.

3. The equivalent exposure times of the various plates differ somewhat. Is it possible to account for the discrepancy in this way? This I have discussed on page 210. In addition we measured the diameter of the Moon on the Sproul plates made from negatives exposed three seconds and two seconds respectively. These differ in effective exposure about the same amount, as the Sproul and Lick plates measured. The diameters of the Moon on these two Sproul plates are the same.

I can think of no other probable source of error. It is my belief that these measures show that these arches have changed in the twenty-six minutes time interval and that they are going outward from the Sun. Assuming the measures are correct, this would mean that these arches are receding from the Sun at the rate of about ten miles per second.

There are many other places in the corona that one feels reasonably certain have changed but they are either too indefinite to measure or one feels that they might be due to some photographic defect. It is not unusual to find streamers issuing from small projections on the prominences. For example, from each of three tips of the Southeastern Prominence there issues a stream and each stream assumes approximately the form of the arch above them.

There was an exposure of forty-five seconds made with this same lens (sixty-two and a half feet focal length) at the Sproul Station. Miss Smedley, an assistant at the Observatory, and myself concluded independently from an examination of this photograph that no one could guess from the shape of the long streamers of the corona that there was a violently disturbed region in the Sun immediately below them. As a matter of fact, the long streamers may not be immediately above the prominences tho they appear to be in the photograph. But no one can tell by an examination of the outer corona that the Sun's surface was at that time very active.

There was another feature of this corona which I believe is unusual. Ordinarily the polar rays seem to be arranged symmetrically with regard to an axis which differs, but not much, from the rotation axis of the Sun. This difference is a function of the position of the Earth in its orbit and of other things. Moreover, if one measures the polar coördinates of the points on a polar ray, measuring the vectorial angles from the west extremity of the Sun's diameter, he will generally find for a polar ray west of the axis of symmetry that the vectorial angle decreases as the radius vector increases, and for a polar ray east of the axis of symmetry that the vectorial angle increases as the radius vector increases. That is, that the polar rays are curved away from the axis of symmetry. In the corona of 1918 the polar rays likewise curve away from the axis of symmetry, but in such a way that whether the ray is east or west of the axis of symmetry, the vectorial angle decreases as the radius vector increases. That is, the polar rays east of the axis of symmetry are curved away from it very much less than those west of it, and it is easy to show that this is not a projective effect. The appearance of these streamers suggested that some sort of current had changed somewhat the direction of all these rays.

PRELIMINARY ORBITS OF FOUR BINARY STARS[1]

By R. G. Aitken

In the early days of double star astronomy the great question to be answered was: "What is the law of the force which governs the observed motions in stellar systems?" Theories of the motion based upon the assumption that the controlling force was identical with that described by Newton's law of gravitation had, indeed, been formulated soon after the appearance of Herschel's epoch-making paper, in 1803, "Account of the Changes that have happened during the last Twenty-five Years, in the relative Situation of Double-stars; with an Investigation of the Cause to which they are owing;" it remained to test their adequacy by accurate measures of a large number of systems. Such measures were accumulated by the labors of many eminent astronomers in the course of the nineteenth century, and it has long been known from them that the law of gravitation permits us to represent the observed motion and predict the future motion in binary star systems within the limits of the unavoidable errors of measurement. In the few cases in which periodic groupings of the apparent positions indicate systematic departure from pure elliptic motion, it has been possible to find adequate explanation in the assumption that one or the other of the visible stars of the pair is attended by an unseen companion and the correctness of this assumption is now not questioned. In fact, in the case of *Epsilon Hydrae*, its correctness has been demonstrated. Schiaparelli, in 1888, discovered that the principal star of the Struve pair was itself a close unequal pair. In 1903 I computed the orbit of this close pair and Seeliger soon afterward showed that its motion in its fifteen-year-period orbit fully accounted for the observed irregularities in the motion of the wider long-period Struve system.

All this does not mean that it is no longer necessary or desirable to measure the visual binary stars; it simply means that interest has shifted largely from the motion in the particular system and the laws governing it to the information we can gain from a comparative study of the orbits of many systems as to the origin of the binary stars and their relation to single star systems. Of at least equal importance is the knowledge of the masses of the stars which we can obtain directly only from the visual binary systems whose orbits are known and whose parallax has been measured.

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[1] Read at the Seattle meeting of the Pacific Division A. A. A. S. Details of the computations will be printed later elsewhere.

For such investigations the orbit elements are not all of equal importance and an accurate knowledge of them all, tho desirable, is not essential. So far as we can judge at present, the time of periastron passage, the orientation of the orbit plane and of the orbit in its plane have little bearing upon questions of binary star evolution; the eccentricity of the orbit, the period of revolution and the length of the major semi-axis are the three important elements. The last two are the only ones needed for mass determinations. It is worth while, therefore, to compute approximate orbits of binary stars which promise fair values of these three elements, even tho the data do not suffice for reliable determinations of all the elements. The orbits I present today, as will appear, fall into this category of approximate solutions.

The first two systems—Σ 412 and β 552—have been well observed over relatively short arcs, but we have earlier estimates and other data which help to define the apparent ellipse in each case. The former system was discovered by Struve in 1830 when the two components, of equal brightness, were separated by 0″.7. It has been observed regularly ever since and the companion, to date, has described an arc of 173°, with distances slowly diminishing to a minimum of 0″.2 about the year 1915 and since then very slowly increasing. Herschel listed a distant companion in 1781, but did not see the close pair. This fact leads to the inference that the angular separation at that time was but little, if at all, greater than in 1830, when Struve discovered it. On this hypothesis the apparent ellipse is defined within quite narrow limits and the following elements result:

Revolution period	270 years
Date of periastron passage	1917.3
Eccentricity	0.555
Major semi-axis	0″.49
Nodal point	97°
Inclination of orbit plane	41°
Angle between nodal point and periastron point	348°

Position angles decreasing with the time.

According to Boss, the system has a centennial proper motion of 3″.5 in 141°, and this value finds confirmation in the measures connecting the Herschel companion with the binary. That companion is, therefore, probably an independent star. The eccentricity is rather smaller than might be expected of a star with so long a period; it is, in fact, close to the average value for all known visual binary star orbits. The parallax is unknown, but if we assume the mass to be twice that of the Sun, the computed parallax is 0″.0086, a result which seems reasonable for a star of its magnitude (5.9) and spectral class (A2).

The orbit of β 552 resembles that of Σ 412 in its eccentricity and in the size of the *apparent* ellipse, but the period of revolution is only one-third as long. The well observed part of the orbit extends over but 120° but, fortunately, we have also the early estimates of position made by Burnham in 1874 and 1877. If these are even approximately correct the available arc is nearly 287° and the orbit is now quite determinate. Elements were indeed computed by See in 1908 but these fail to represent the later motion[2]. The elements now obtained are:

Period	86 years
Periastron	1886.35
Eccentricity	0.51
Major semi-axis	0″.56
Nodal point	145°.8
Inclination	39.35
Angle between node and periastron	309.6

Angles increasing.

We have values of the parallax of the system determined both by the photographic and by the spectroscopic method, the former being +0″.014 (absolute), the latter, +0″.027. Using the elements just given these lead to the mass values 8.7 ⊙ and 1.2 ⊙, respectively. Now the spectral class of this 6.7 magnitude star is F5 according to Miss Cannon, F6 according to Adams, and evidence from several sources leads us to believe that stars of this class are not likely to be of very great mass. Recalling also the fact that the average mass value of those binaries for which this value is well determined is about 1.7 ⊙, I incline to the opinion that the spectroscopic parallax is nearer the truth than the photographic one.

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[2] After this paper had been written, I received the March, 1920, number of the *Monthly Notices R. A. S.* containing Mr. J. Jackson's paper on "The Orbits of 20 Double Stars." Two of these stars are Σ 412 and β 552 and it is of interest to compare Mr. Jackson's values of the period, major semi-axis and eccentricity of these systems, derived from measures to 1913 inclusive, with those I have computed from measures to 1920 inclusive. Mr. Jackson's values are as follows:

Period	216.9 years	88.2 years
Major semi-axis	0″.407	0″.627
Eccentricity	0 .545	0 .519

The eccentricities agree almost precisely with those given above; the period and major semi-axis are in the one case smaller and in the other larger than my values but the two elements in each case vary in the same sense so that the hypothetical parallaxes are in close agreement with those found from my elements.

This raises an interesting question: "May we some day hope to use our knowledge of stellar masses as one criterion in estimating the systematic errors of different sets of parallax values?" It would obviously be unsafe to generalize upon the basis of the data now available, but even now I am of opinion that in particular cases we may use the resulting mass of a binary system to aid us in our estimate of the reliability of its published parallaxes The system β 395 is a case in point. Flint, some years ago, from meridian circle observations, found the absolute parallax to be +0″.36. The orbit elements of this binary are quite accurately determined, the period being 25.0 years, the major semi-axis 0″.66. Combined with Flint's parallax, these data lead to the very improbable mass of only 0.009 ⊙. There is no question here but that the spectroscopic parallax, +0″.066, with its corresponding mass of 1.6 ⊙, is by far the more accurate.

The other two orbits which I wish to present differ in almost every particular from the two already described and at the same time are in striking contrast to each other in their eccentricity. β 1185 was discovered by Burnham with the 36-inch in 1890 and except for measures on four nights in 1896 by Schiaparelli has since then, so far as I know, been measured only by me. The maximum separation of the two components is less than a quarter of a second of arc, and, at minimum, the star appears absolutely round when viewed with the highest powers. The measures also show that the orbit plane is inclined at a high angle to the plane of projection. When the distance is near its maximum the difference in the brightness of the two components is quite appreciable and the quadrant determinate; moreover, the measures can only be harmonized on the assumption that the companion is now in the position it occupied at discovery in 1890 and that in the years 1906-1911 the elongation was in the opposite quadrant and was slightly greater. We therefore have the elements:

Period	28.9 years
Periastron time	1917.8
Eccentricity	0.19
Major semi-axis	0″.23
Nodal point	22°.5
Inclination	77°
Angle between node and periastron	310°.4

Angles decreasing.

The period and eccentricity are, I think, very nearly correct; the uncertainty in the value of the major semi-axis is a little greater, but the value given I regard as a fair approximation. It appears that the orbit is more nearly circular than that of the planet *Mercury*. Only seven other visual binaries are known with orbits so slightly elliptic. The spectral class is Go, the photometric magnitude 7.7. Assuming a mass of 2 ⊙ the elements give a parallax of $+0''.019$. As the mass is probably not greater than the value assumed, this hypothetical parallax may be considered as the minimum to be expected.

The fourth system OΣ341, is one of quite unusual interest. Discovered in 1843, the scattered positive observations to 1886 indicated relative fixity of the two components at an angular separation of about $0''.45$. No measures were made in the intervals 1852-1865, 1872-1882, and 1886-1898, but Otto Struve, in 1877, reported that he could see no trace of the companion. No significance was attached to this report, however, until early in 1898, when Hussey, then engaged upon the remeasurement of all of the Otto Struve stars, also failed to see the companion. At his request I examined the star at that time and found it single. Later in the same year Hussey was able to detect a very slight elongation and in 1899 it was clearly double. The distance increased, at first rapidly, then more gradually, until it reached a maximum of nearly $0''.5$ about the year 1910. I have followed the system carefully since 1900, always using in its identification the chart prepared by Hussey and myself in 1898. In 1914 I found that the distance had decreased to $0''.34$; in 1916, to $0''.24$; in 1917, to $0''.15$ or less. In 1918 elongation was barely perceptible, but in 1919, the measures gave $0''.19$, and the distance is now fully $0''.28$. The components differ in brightness by at least three-quarters of a magnitude and there is no question but that the companion is now in the same quadrant as in 1916 and in 1900.

From these facts and the further one that the variation in position angle is small, it is clear that the orbit is one of extreme eccentricity lying at a high angle of inclination to the plane of projection. The period of revolution is very definitely known from the apparent conjunctions of 1898 and 1918, and the time of periastron passage cannot differ by more than a fraction of a year from that of apparent conjunction. The eccentricity, too, is well determined, but the other elements are relatively uncertain. The major semi-axis may have any value between $0''.25$ and $0''.30$.

The best solution I could obtain by graphical methods and later arbitrary variation of the elements gave the following results:

Period	19.75 years
Periastron time	1917.85
Eccentricity	0.96
Major semi-axis	$0''.30$
Nodal point	104°
Inclination	$77^\circ.5$
Angle between node and periastron	149°

Angles increasing.

The adopted period fits the early observations very well, the elongations coming at the times when positive observations were made, the conjunctions at times for which we have no measures. In particular, one conjunction coincides closely with the date in 1877 when Otto Struve could see no trace of the companion.

The spectral class is G0, the BD magnitude 7.5. Assuming, once more, a mass of 2 ☉, the parallax will be $+0''.0326$ if the major semi-axis be taken as $0''.30$, and $+0''.0272$ if we adopt what appears to be the minimum possible value of $0''.25$. The parallax should therefore be measurable with considerable accuracy.

The chief interest in the system, however, attaches to the eccentricity, 0.96. For only one other system has so high a value been found. This is *Zeta Bootis*, for which Hertzsprung and I, independendtly, found about three years ago that the law of areas could best be satisfied by assuming extremely rapid angular motion at the time of approximate conjunction and an eccentricity of 0.96 to correspond. The two components of *Zeta Bootis* are very nearly of equal brightness and the quadrant always indeterminate. The interpretation of the measures just given may therefore be open to some question tho I believe it to be correct. But in the case of OΣ 341, as I have pointed out, the quadrant is never in doubt when the two components are separately visible and the general form of the apparent ellipse is therefore well determined. A value of e as low as 0.94 definitely fails to represent the observations.

Now it has repeatedly been shown, and most recently and convincingly by Jeans, that so great an eccentricity cannot be developed by the internal forces of a binary system which has originated by fission of a single mass. To account for it we are driven to a search for adequate external forces or to the conclusion that such systems were evolved thru some process other than that of fission. We are being led to consider seriously the hypothesis that there are two (or more) classes of binary systems which have been developed by entirely different evolutionary processes A number of interesting suggestions along these lines have been made, but it is my opinion that we must wait for more data before we can accept any theory as more than a working hypothesis. It is the desire to secure such data that provides the chief incentive for the observation of the visual binary stars at the present time.

June 3, 1920.

SOME NOTES ON NOVA AQUILAE III, 1918

By E. E. Barnard

I have kept a close watch on *Nova Aquilae* for changes in light and in its physical appearance. A few of my notes may be of interest in connection with the nebulosity found to be receding from the nova by Aitken and Moore. I can give here only a brief reference to these notes, which are very full and which ought to be printed entire later on. I have already referred to the peculiarities of the brightness of this star (*Astrophysical Journal*, **49**, 199, 1919), as seen in telescopes of different sizes, where it was shown that the nova appeared relatively brighter in small telescopes, due mainly to the fact that in such an instrument all the light went to form the image, while in a larger telescope part of it went to form the optical glow about the true image. This feature was very striking and should be taken into account in any investigation of its brightness.

In the latter part of 1918 the star assumed a perfect planetary disk. This was not simply a large ill-defined image, which it had later on, but a disk as sharply defined and clear cut as the disk of Neptune, which it very much resembled, and of a uniform light. This is what I have referred to as "a planetary disk." This disk was measurable and seemed to be expanding. The apparent increase in diameter was about 1" from October 5th to December 17, 1918. The [illegible] of the star made measures somewhat difficult, [illegible] the increase in size was real. This disk, which was [illegible] was of a pale whitish yellow color, and was im[illegible]. Out of focus [illegible], outside the [illegible] the usual crimson image due to the Hα [illegible] at a certain stage in the decline [illegible]. This was [illegible] and small and was surrounded [illegible].

[illegible] again became observa[illegible] appearance in the large telescope. [illegible] disappeared and the star was a [illegible] stellar it was not the [illegible] seen. There was no [illegible]. Out of focus it presented a [illegible] with no special con[illegible] May and June, the focal image was [illegible] with a beautiful blue color.

The disk was large but not planetary. The out-of-focus image was all blue with an ill-defined dark blue core. When best seen the star was almost a robin's egg blue.

On 1919, June 5th, the image was large, white and ill-defined and was placed in a very close blue atmosphere. Rough diameter 1″.4. With power of 700 it was whitish or whitish yellow with but little blue about it.

In the last of June the image was perhaps entirely stellar—no longer large or planetary—with a bluish glow close about it. It gave the impression of a white star seen through a blue envelope, which in poor seeing made the entire image a strong blue. The diameter was 3″.7 in a larger, fainter glow 24″ in diameter. The central image was pale blue. "It looked as if there might be a small nebulosity very close preceding and following."

September 23d. Greenish blue. In best focus it was a pale, whitish, ill-defined image, perhaps stellar. It was involved in a greenish blue atmosphere that fitted close about it as if the star were white and had a greenish blue envelope surrounding it. The diameter of this envelope was 2″.0. Later, with very bad seeing, it appeared like a small greenish blue ball 4″.2 in diameter, due to the mingling of the light of the star and the envelope.

On September 27th it was a small whitish stellar point in a greenish blue halo 5″-6″ in diameter. The out-of-focus image was large, irregular, and bluish white with no central core. In focus the image was perfectly stellar and whitish. The bluish glow surrounding it was shifted with respect to the star by looking in at the side of the eye-piece. It was therefore optical. With 700 diameters the star was a very small white stellar point in a greenish blue glow whose diameter was 3″.7.

November 22nd. Bluish. A little whiter in the middle. The out-of-focus image was bluish with no central condensation. Bad seeing.

December 2d. Intensely blue but blurred from bad seeing. Out-of-focus image blue with no central core.

In bad seeing the image was mixed up with the bluish glow about it and this produced an ill-defined very blue image of the star, while in good definition the true image was more white than blue.

The phenomena during the present season so far have been of a slightly different nature.

On 1920, May 13th, the nova was bluish white—almost white—involved in a very close dense nebulosity which was further surrounded by a larger and much fainter glow. The star BD +0°4023, 5′ south preceding the nova, did not show this appearance of dense nebulosity. The glow in which the nova was imbedded gave it the appearance of a small stellar nebula.

On May 20th the dense glow about the nova did not seem to have much of the blue color. It seemed to become denser later on in the season as the star became slightly fainter.

On June 5th the nova was whitish with a slight bluish tinge. It very much resembled Miss Mackie's *Nova Ophiuchi* ($\alpha 18^h\ 10^m$, $\delta +11\frac{1}{2}°$) except that there was slightly more blue to *Nova Aquilae*. It resembled a small bright nebula, while the BD star south preceding was free from this nebulous appearance.

On June 10th it was perfectly stellar, whitish or possibly slightly yellow in color. It was imbedded in a close nebulous glow 3″.2 in diameter with a fainter glow 30″ in diameter. The star presented the same appearance it had shown for a long time. A sketch compared with that of May 13th showed the same appearance, so that the nova had apparently not changed for several months.

On June 12th it looked like a small bright stellar nebula. The focus of the stellar image was the same as that for the BD star. It was imbedded in this close bright glow whose diameter was 3″.4.

On June 26th it was stellar and involved in a close bluish white nebulosity.

On July 8th, with good seeing, it was perfectly stellar, closely surrounded with a bluish white glow. There was no special color to the out-of-focus image, which had no central core. With the eyepiece thus out of focus the BD star 5′ south preceding had a reddish ill-defined core. In focus this star was slightly yellowish. There was no difference in focus between the nova and this star. The diameter of the glow about the nova was 3″.7.

These are only a few of my many notes pertaining to the nova. The diminution of brightness has been slow of late.

Following are the magnitudes with the 4-inch finder of the 40-inch telescope since June 5th. They are on the Harvard scale.

	M		M
June 5	8.4	June 24	8.5
June 8	8.4	June 26	8.3
June 10	8.5	June 29	8.5
June 12	8.3	July 3	8.5
June 15	8.4	July 7	8.4
June 17	8.4	July 8	8.5
June 22	8.4		

As will be seen, the star has been essentially constant in its light for over a month. The slight apparent fluctuations are probably not real. Comparisons with BD + 0°4023 in the 40-inch telescope made the nova, at the same times, nearly one magnitude fainter than the above values.

Recent photographs with the 6-inch and 10-inch Bruce lenses differ in the appearance of the nova. With the 6-inch the image is soft and hazy and quite different from the images of neighboring stars. With the 10-inch this peculiarity is not present.

Yerkes Observatory,
Williams Bay, Wisconsin.
1920, July 10.

MISS MACKIE'S NOVA OPHIUCHI

$(\alpha\, 18^h 10^m,\ \delta + 11^\circ 35')$

By E. E. Barnard

This star has presented a more nebulous appearance than *Nova Aquilae*. When I first observed it on 1919, October 28th, it was $8^m.5$ on the BD scale and was slightly yellow. The in-focus and out-of-focus images showed nothing different from that of an ordinary star. There was nothing in any way suggestive of a nova. On November 1st the star was yellowish with no central core in the out-of-focus image. Its brightness had not changed. On this date I measured its position with respect to the star Leipzig A. G. C. 1 6468. Position of the nova:

$$1919.0 \quad \alpha\ 18^h 10^m 20^s.45. \qquad \delta - 11^\circ 35' 15''.8$$

On November 4th it was a magnitude brighter. The out-of-focus image seemed to have a red or scarlet central core, but it was too low to tell much about it.

November 11th. It was less bright. In focus the star was yellowish with a fringe of scarlet rays. Out of focus the image was a beautiful scarlet, small and well-defined, surrounded by a bluish or grayish green ray system. The glow about it seemed to be optical. There appeared to be no nebulosity about it. Its appearance was that of a typical nova.

November 18th. The out-of-focus image did not show any central core.

December 2d. The star was a strong yellow in the 40-inch. The out-of-focus image was red but was shifted from the center by the low altitude.

1920, May 13th. Very closely nebulous in appearance, like a small, bright, whitish nebula. The focus was the same as for the other stars. There was no core to the out-of-focus image. One would single it out at once from all the other stars from its appearance.

May 25th. Very white and hazy, like a very small, bright stellar nebula.

June 5th. It appeared to be a very small stellar nebula, much like some of the Wolf-Rayet stars. There was no difference of focus from the ordinary stars, but it could not be brought to a definite focus. It would readily be taken for a small stellar nebula.

June 10th. The stellar image could scarcely be seen for the brightness of the nebulosity in which it was imbedded. The focus was 4 mm. outside that for the ordinary star. The diameter of the nebulosity was 2″.3, in the center of which the star itself appeared as a very small point of light. A feebler glow extended farther out. The nova appeared like a duplicate of *Nova Aquilae*, but somewhat fainter and smaller. To all appearance it was a small nebula.

June 12th. It was a very small stellar nebula. Out of focus the stellar image could be seen imbedded in the close brightish glow. The diameter of this glow was 2″.4.

June 17th. The star was densely hazy like a very small stellar nebula.

June 24th. The nova was involved in a close, dense nebulosity. The focus was much outside that for an ordinary star.

July 8th. It resembled a small nebula in which the star was almost lost. The diameter of the nebulosity was 1″.5. The best focus was 4 mm. outside that for a star.

July 10th. It was a small stellar point in a very small dense nebula. At 5 mm. outside the regular focus it appeared like a minute nebula 1″-2″ in diameter, with a tiny nucleus.

Following are the determinations of magnitude with the 4-inch finder of the 40-inch telescope. Since it ceased to be visible in the finder I have compared it with small stars near; but as these observations are being continued, only the finder observations of brightness will be given here. They are on the BD scale.

MAGNITUDES OF NOVA OPHIUCHI WITH THE 4-INCH FINDER

	M		M
1919, October 28	8.5	1919, November 18	9.3
1919, November 1	8.5	1919, November 19	9.0
1919, November 4	7.5	1919, November 22	9.2
1919, November 11	8.7	1919, November 23	8.8
1919, November 12	8.7	1919, December 2	9.2
1919, November 17	8.6		

The most striking change was about November 4th, when it had risen a whole magnitude.

It is probable that the larger glow mentioned about *Nova Aquilae* and about *Nova Ophiuchi* is instrumental and has nothing to do with any nebulosity about either star.

Yerkes Observatory,
Williams Bay, Wisconsin.
1920 July 12.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1920

BY MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter	Sept. 5, $11^h 5^m$ A.M.	Last Quarter	Oct. 4, $4^h 54^m$ P.M.
New Moon	" 12, 4 52 A.M.	New Moon	" 11, 4 50 P.M.
First Quarter	" 19, 8 55 P.M.	First Quarter	" 19, 4 29 P.M.
Full Moon	" 27, 5 57 P.M.	Full Moon	" 27, 6 9 A.M.

The third eclipse of the year will be *a total* eclipse of the Moon on October 27th, the beginning visible generally in the western part of North America, the Pacific Ocean and eastern Asia, the ending visible generally in the western portion of the Pacific Ocean and the eastern hemisphere nearly to the Atlantic Ocean. The circumstances of the eclipse are as follows, Pacific Time:

Moon enters penumbra	October 27th, $3^h 24^m$ A.M.
Moon enters umbra	October 27th, 4 26 A.M.
Total eclipse begins	October 27th, 5 29 A.M.
Middle of eclipse	October 27th, 6 11 A.M.
Total eclipse ends	October 27th, 6 54 A.M.
Moon leaves umbra	October 27th, 7 57 A.M.
Moon leaves penumbra	October 27th, 8 59 A.M.

The autumnal equinox, the time when the Sun crosses the equator from north to south, occurs September 23d, $12^h 29^m$ A. M. Pacific Time.

Mercury is very close to the Sun on September 1st and passes superior conjunction on September 8th becoming an evening star. It gradually moves out to greatest east elongation reaching this on October 24th. The elongation, 24°8′, is rather greater than the average greatest elongation, but the planet is far south of the Sun and the interval between the setting of the Sun and planet is only about one hour, so the conditions for visibility are not at all good, as is generally the case in greatest east elongations which happen in the autumn. On September 8th *Mercury* is in very close conjunction with *Saturn*, the distance between the planets being only 6′; but unfortunately both planets are within one day of conjunction with the Sun at the time.

Venus is an evening star gradually increasing its distance from the Sun. On September 1st the planet remains above the horizon only a little more than half an hour after sunset. This interval increases to about an hour and one-half by the end of October, so that the planet is becoming a rather conspicuous object in the evening twilight during October, altho not nearly as bright as it will be during the late winter and early spring of 1921.

Mars is still in fair position for observation during the early evening. On September 1st it sets shortly before 10 P. M. and at about half after eight on October 31st. During the two months the planet moves about 46° eastward from *Libra* thru *Scorpio*, and into *Sagittarius*. On September 17th it is in conjunction with *Antares*, *α Scorpii*, the planet passing a little less than 3° north of the star. Both planet and star are of decidedly ruddy color, but the planet is twice as bright as the star. The planet continues to grow less bright losing nearly half its light during the two months, so that at the end of the period it is about as bright as a standard first magnitude star. Its distance from the Earth increases from 113 millions of miles on September 1st to 144 millions on October 31st.

Jupiter passed conjunction with the Sun on August 22nd and became a morning star drawing slowly away from the Sun, but it does not reach a sufficient distance from that body to be easily seen in the morning twilight until well after September 1st. By September 15th it rises about an hour and a half before sunrise. By October 31st it rises shortly before 2 A. M. During the two months it moves about 11° eastward and 4° southward in the constellation *Leo*.

Saturn passes conjunction with the Sun on September 7th and becomes a morning star. By the end of the month it rises rather more than an hour and a half before sunrise so that it is then easily visible in the morning twilight. By the end of October it rises at about half after two in the morning. During September and October it moves about 6° eastward and 3° southward in *Leo*. It is moving in the same general direction as *Jupiter* but at a much smaller rate so that the distance between the bodies diminishes about 5° during the two months.

Uranus passed opposition with the Sun on August 26th and is therefore above the horizon thruout nearly the entire night during early September. By the end of October it sets at about 1:30 A. M. It moves about 2° westward during the two months away from the fifth magnitude star *σ Aquarii* near which it was during August. It will therefore not be as easy to identify.

Neptune is a morning object on the border of the constellations *Cancer* and *Leo*, too faint to be seen without a telescope.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE RELATIVE SURFACE INTENSITY OF THE COMPONENTS OF ECLIPSING VARIABLES

The interesting discussion in the June number of these PUBLICATIONS on the relations between the surface intensity, the density and the mass of the components of the binary star *Sirius* by Director Campbell raises a question which had already been noticed and commented on by me in the "Spectroscopic Orbit of the Eclipsing Variable U Coronae," which is about to be published.

As is well known, when a reliable photometric orbit of this class of stars is available and when the spectra of both components are measurable, we can obtain not only the mass of the two bodies and the dimensions of the orbit but also their diameters, densities and surface intensities.

On examining the photometric orbits in Shapley's list[1] several stars will be found in which there is a considerable disparity in the diameters of the two components and in many cases very great differences in their surface intensities but it is only when both spectra have been observed that we can compare the surface intensity and spectral type of the components. In the variables *β Lyrae*, u *Herculis* and *Z Herculis* both spectra have been measured and the spectroscopic orbits determined. While these three stars each show distinctly that a similar or nearly similar spectral type is associated with considerably different surface intensity, I will nevertheless confine myself in this note to two variables whose spectroscopic orbits have been determined here.

Two separate determinations of the photometric orbit of RS *Vulpeculae* by Shapley[1] and Stewart[2] differ greatly tho agreeing in assigning greatly differing brightness per unit area or, as it is called here, surface intensity to the two components. The later orbit by Stewart, as presumably based on more accurate photometric observations, has been used. According to this and the spectroscopic orbit[3] the fainter component has five times the diameter of the brighter but only one four-hundredth the density. The surface intensity of the fainter is only one twenty-eighth that of the brighter while the spectral type is nearly the same, the primary being about B8 and the secondary B9.

[1] *Contributions from Princeton Observatory*, No. 3.
[2] *Ap. Jour.* **42**, 315.
[3] *Jour. R. A. S. C.* **14**, 1.

While the secondary minimum was not observed in U *Coronae*, the spectroscopic observations show the spectrum of the second component, both being of the same type B5. Consequently the fourth of Shapley's orbits which assumes the brighter star as giving seventy-four per cent of the light of the system was taken as the most likely, altho little difference in the results, except to increase the ratio of surface intensities, would be given by using any of the other orbits. The fainter star has sixty per cent greater radius, a density one-twelfth and a surface intensity only about one-eighth that of the brighter, while the spectral types are the same.

While it is desirable to have more accurate photometric observations and orbits of these two stars, there can be no reasonable doubt of the substantial accuracy of the relative surface intensities and densities of the components. From these two cases and from those of other eclipsing variables, it would appear as if the surface intensity was not solely a function of the spectral type but had also some relation to the density. In eclipsing variables the star of smaller density has also the smaller surface intensity while in the visual binary *Sirius*, whatever reasonable assumptions are made of the value of the density and surface intensity, the fainter component of lower brightness per unit area must have the higher density. While it is true that the conditions in eclipsing variables and visual binaries are very different and while it is possible these systems may have had a different origin and mode of development, it is evident that, until more information is available, considerable caution must be used in assuming that the surface intensity of two stars of the same spectral type is the same.

J. S. PLASKETT.

THE NEBULOUS DISK SURROUNDING NOVA AQUILAE, NO. 3

In an earlier note[1] I described *Nova Aquilae*, No. 3, as it appeared in the 36-inch telescope in August-September, 1919, and gave measures of the diameter ($2''.37$) of the nebulous disk[2] which surrounded the nucleus. At that time I called attention to the apparent increase in the size of this disk in the interval since October, 1918, when Barnard's measures gave a diameter of $0''.65$.

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[1] *Publ. A. S. P.*, **31**, 283, 1919.

[2] The term *disk* in this note is used to describe the image of the nova, which is in focus when the eye-piece is drawn out 8 mm. beyond the normal stellar focus. According to Keeler's color-curve of the 36-inch lens, light of wavelength λ 4980 is brought into focus at this point. The N_1 and N_2 lines of nebulium have wavelengths λ 5007 and λ 4959 respectively.

I have re-examined the nova and made measures of the disk on two nights in the present season, June 7th and July 5th, using a 1000-power eyepiece. At the normal stellar focus the nucleus appeared as sharp as an ordinary star of the same magnitude, but it was surrounded by a halo not seen about an ordinary star. This, of course, was due to the out-of-focus light from the nebulous envelop of the nova, and when the eyepiece was drawn out 8 mm. beyond stellar focus it condensed into a small circular disk of bluish-green color. The nucleus was now out of focus and was completely lost in the light of the nebulous envelop, which, as the spectrograms show, is concentrated almost entirely into the N_1 and N_2 lines (or rather bands) of nebulium—the so-called "green" nebular lines. But the disk, while having the same general appearance as a year ago, was fainter and larger, my measures on the two nights giving 3″.69 and 3″.58, respectively, for the diameter. These values agree well with the results of Barnard's measures of the "close bright glow" about the star on June 12th and July 8th, the mean of his measures being 3″.55 and the mean of my measures of the disk 3″.63. The fact that the envelop has expanded during the past year is fully substantiated by the spectrograms which are described by Dr. Moore on another page.

Professor Barnard has probably kept a closer watch upon this nova than any other observer and his article, also printed in the present number of these PUBLICATIONS, is of great interest.

July 15, 1920. R. G. AITKEN.

RECENT SPECTROGRAPHIC OBSERVATIONS OF NOVA AQUILAE III

Spectrograms of *Nova Aquilae* III have recently been secured (May 23-June 11, 1920) with a one-prism spectrograph and the 36-inch refractor, on which the N_1, N_2 and $H\beta$ bands have the peculiar sinuous form, observed in the spectrum of this object in the summer of 1919,[1] by Messrs. Wright, Moore and Shane. Maximum and minimum sinuous effects in the bands are obtained, as last year, when the slit of the spectrograph is placed centrally across the nova disk in position angles respectively 202° and 112°.

Several conspicuous changes appear to have occurred in the bands since the observations of last year. They are noticeably wider in a direction at right angles to the length of the spectrum, corresponding to an image disk of about 4″ diameter for N_1 and N_2, and of 1″.5 for the Hβ band, as compared with disks, respectively, of 3″.0 and 1″.0 diameters,[2] in August 1919. Marked changes in the relative intensities of different portions of the bands have taken place in the interval of ten months, which appear as a diminution of intensity of the central band (5003-5012 A) and a corresponding increase in the intensity of the outer portions of the band (5003-4978 A) (5012-5038 A).

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[1] *L. O. Bull.*, **10**, 30 and 32, 1919.
Publ. A. S. P., **31**, 269, 1919.

One of the most striking changes has occurred in the portions of the central band (5003-5012 A) originating at the north and south edges of the nova disk which on the spectrograms of last year were sharply cut off respectively on the violet and red sides. On the recent plates, radiations of wavelengths 5003 to 5012 A are present in the light received from both the north and south edges. A dark division extending along the central part of the spectrum and separating the upper and lower halves of the bands is distinctly shown on the recent spectrograms, in both position angles of the slit, 202° and 112°.

Aside from numerous variations in relative intensities, the internal structure of the bands appears to have suffered little change. Measures of the positions of the principal maxima and minima of the bands give the same wavelengths for these as obtained last year, with no apparent change in the great width of the N_1, N_2 and Hβ bands (about 60 angstroms) previously observed.

A further interesting observation, to which attention was not called in our previous paper, is the apparent symmetrical displacement of the violet and red maxima with reference to the normal positions of the nebulium lines (or centers of the bands). For each maximum displaced toward the violet there is a corresponding one displaced an equal amount toward the red. The red components are in general of less intensity than the corresponding violet ones.

J. H. MOORE.

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[2] In the interesting notes by Professors Barnard and Aitken, appearing in this number, it will be observed that their micrometric measures give smaller values of the diameters of the green disk than those obtained above. It seems probable that the spectrographic measures of the diameter are affected to some extent by the presence of astigmatism in the spectrograph and by the unavoidable drifting of the image on the slit.

OBSERVATIONS OF THE SPECTRUM OF *o* CETI IN 1919

The spectrum of the long-period variable, *o Ceti*, was observed in the visual and ultra-violet regions during the 1919 maximum and decline to minimum. The purpose of this investigation was to determine the extent to which conclusions based on previous observations in the photographic region would be confirmed when extended to longer and shorter wavelengths, and to discover any additional features of interest in the star's spectrum. The observations in the visual region were made with 1-prism and 3-prism spectrographs attached to the 36-inch refractor of the Lick Observatory, while the observations in the ultra-violet region were made with the large quartz spectrograph designed by Mr. Wright for use with the Crossley reflector.

The most conspicuous features in the visual portion of the spectrum are the many and prominent absorption bands, over fifty having been measured between wavelengths 5550 A and 6700 A. All of these are sharp toward the violet and fade away gradually toward the red. Most of the bands in *o Ceti* of shorter wavelength than 5840 A, *i. e.*, in the yellow and blue, have been identified by Fowler with bands of titanium oxide. In the visual region, between 5500 A and 6700 A, as observed in the present investigation, there are no fewer than thirty coincidences with the band spectrum of titanium oxide. There remain twenty bands in *o Ceti* which apparently do not belong to this substance. Six of these have been found to coincide with bands which ordinarily occur in the arc spectrum of yttrium. Of these six, three coincide respectively with the first band in each of the three known groups in the yttrium band spectrum. While the origin of these bands can not be definitely attributed to yttrium, it is quite probable that bands due to yttrium in some form are represented in *o Ceti*. The remaining fourteen bands have not been identified.

It has been noted by previous observers that as *o Ceti* decreases in brightness, the absorption bands in the photographic region become stronger. This same effect was observed in the visual region during the 1919 decline to minimum. When the star had fallen 5.4 magnitudes below maximum, the absorption in some of the bands seemed to be complete. On a spectrogram secured at that time, the region about Hα was entirely burned out by overexposure, yet there was no trace of spectrum in the nearest heavy absorption band at 6200 A.

A relative strengthening of the red end of the continuous spectrum as *o Ceti* decreased in brightness was observed by Sidgreaves. This effect has been confirmed at the recent decline to minimum. A 1-prism plate was obtained in July, 1919, about the time of maximum, and a second in November after the star's light had decreased 3.7 magnitudes. On the latter date the spectrum at Hα was two or two and a half times as strong relative to the spectrum at 5200 A as on the former. This effect became even more pronounced as the star grew fainter. No marked changes in the ultra-violet continuous spectrum were observed, and in view of the fact that no absorption bands occur in this part of the spectrum, it may be suggested that the changes observed in the visual region are in some manner associated with the banded spectrum.

A remarkable feature of the Class Md spectrum is the presence of the Balmer hydrogen series as bright lines. The spectrograms of *o Ceti* obtained in 1919 showed all the hydrogen lines from Hα to Hρ, seventeen in number, to be bright. The strongest line of the series is Hδ. On either side of Hδ the intensities decrease, rather smoothly toward the red but irregularly toward the violet. The irregularities consist chiefly of abnormally faint lines, of which Hε is the principal example. This line is always faint in *o Ceti* and is frequently absent. It has been suggested that its faintness is due to absorption by the H line of calcium within whose limits Hε falls. Other conspicuous examples of abnormally faint lines are Hκ, Hλ, Hμ and Hξ. Of these lines the first three are nearly coincident with iron lines which are very prominent in the arc, and easily reversed. The conditions in *o Ceti* are favorable for the appearance of the iron arc lines as absorption lines. The fourth, Hξ, coincides in wavelength with a strong line of vanadium, an element which is prominent in the star's absorption spectrum. From these coincidences it seems not unlikely that this abnormal faintness of certain hydrogen lines is due to absorption by overlying metallic vapors. This explanation, if correct, would indicate a low level in the star's atmosphere for the hydrogen emission.

Another interesting feature in connection with bright hydrogen series is the abnormal displacement of the two lines, Hα and Hκ. Thruout the entire series of observations Hα was shifted about 1.2A toward the violet with reference to the other hydrogen lines. Hκ, on the other hand, exhibited a different behavior. In July, about one month before maximum light, it was shifted 1.1 A toward the red, while in September, the displacement was 0.3 A toward the red. There is no obvious explanation for these anomalous displacements.

It is desirable that the visual and the ultra-violet spectra of *o Ceti* be studied at future maxima to determine in how far the behavior of the absorption bands and especially of the bright hydrogen lines, as observed in 1919, is repeated.

C. D. SHANE.

SUMMARY OF MOUNT WILSON MAGNETIC OBSERVATIONS OF SUN-SPOTS FOR MAY AND JUNE, 1920

Observations of the magnetic field in sun-spots were first made at Mount Wilson Observatory in 1908[1]. In the beginning only large spots could be observed, but as the methods and instruments were perfected it became possible to detect the polarity of very small spots. Since 1915 daily visual observations have been made of the magnetic field of all sun-spots for which such observations were possible.

The polarity can be determined when the line of sight is not too greatly inclined to the lines of magnetic force, which are perpendicular to the Sun's surface at the center of a spot. Near the Sun's limb polarity determinations are difficult for large spots, and impossible for small ones. The observations are made in the second order of the 75-foot spectrograph of the 150-foot tower telescope, usually with the iron line at λ6173.553. The method of observation and the scheme of classification according to polarity are described in detail, with illustrations, in the *Astrophysical Journal* for April, 1919, and in *Mount Wilson Contributions* No. 165.

The image of the Sun, 42.4 cm. in diameter, is projected upon a sheet of paper and a sketch of the spots is made. The approximate heliographic latitude and longitude of each group is read from a disk upon which the meridians and parallels of latitude have been drawn. The magnetic polarity and field-strength of each spot are then determined by the character of the polarization and the measured separation of the components of a Zeeman triplet.

These magnetic observations will be published in detail, probably in graphical form, but even after a complete scheme of periodical publication has been established, the installments will necessarily be some months late. Meanwhile it seems desirable to print regularly a summary, showing the polarity classification of all sun-spots observed here.

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[1] Hale, *Mount Wilson Contributions*, No. 30, *Astrophysical Journal*, **28**, 315, 1908.

For our own convenience a serial number has been given to each group (col. 1 of the accompanying tables). There is no intention of using this designation in preference to the Greenwich number; in fact, in our own records the Greenwich numbers are adopted as soon as available. In the past few years, however, because of war conditions, the Greenwich numbers have been published very irregularly, and none have appeared since January 1917. Not every Greenwich group has been observed here; also there may be a difference in defining the groups, since at Mount Wilson the polarities of the spots are considered in assigning numbers, so that in some cases two Greenwich groups have been given one number, or vice versa. The last published Greenwich number, No. 7930, was No. 511 at Mount Wilson.

In order to make identification possible, the Greenwich mean time of central meridian passage and the heliographic latitude are given for each group in the second and third columns of the tables. These positions are approximate and may differ somewhat from the measured values obtained at Greenwich. Column 4 gives the maximum field-strength, H, observed in each group, expressed in units of 100 gausses.

The spot groups are divided into three classes, which are designated here as ***unipolar***, ***bipolar***, and ***complex***.

The ***unipolar*** groups are single spots or groups of spots having the same magnetic polarity. This class is subdivided, according to the position of the group in the surrounding calcium flocculi, as follows:

(*a*) Those for which the distribution of calcium flocculi is fairly symmetrical preceding and following the group.

(*ap*) Those which are in the preceding part of the surrounding calcium flocculi.

(*af*) Those which are in the following part of the surrounding calcium flocculi.

The simplest ***bipolar*** group consists of two spots of opposite polarities, the line joining them generally making a small angle with the solar equator. Usually, however, the ***bipolar*** group is a stream of spots, those in the preceding and following parts of the group being of opposite polarity. Generally the change in polarity is near the center of the stream, but it may be on either side of the center. The *bipolar* groups are subdivided, according to the area and distribution of the different magnetic fields, as follows:

(β) Those in which the leading and following members, whether single or multiple, are approximately equal in area.

(βp) Those in which the leading members are the principal components of the group.

(βf) Those in which the following members are the principal components of the group.

($\beta\gamma$) Those in which the bipolar characteristics are shown, but in which there is no marked dividing line between the spots of different polarities. This includes cases where the preceding or following members are accompanied by companions of opposite polarity.

The *complex* groups (γ) are those in which spots of both polarities are so irregularly distributed as to prevent classification as *bipolar* groups. The class is small but contains many of the large very active groups. It should be noted, however, that unipolar spots and the chief components of bipolar groups may occasionally have small companions of opposite polarity, which play such a minor and sporadic part in the group that they are disregarded in the classification.

In the tabulation of the polarities an x indicates that the group was photographed or seen on that date, but that no polarity observation was made of it. The direct photographs made at the 60-foot tower telescope are available for these additional data. At the foot of each column is given the number of groups observed that day. When the column for any day is blank, and a dash is used instead of the number of groups, it indicates that no observations were made on that date. If the Sun was observed but no spots were visible, a zero will be found at the foot of the daily column.

Since the minimum of 1913, unipolar groups and the preceding spots of bipolar groups in the northern hemisphere have had a polarity like that of a north-seeking pole, called positive in this summary. In the southern hemisphere similar spots are of opposite polarity, and are called negative. There are very few exceptions to this rule, and unless the contrary is noted it is to be understood that the group is "regular" in polarity.

MAGNETIC CLASSIFICATION OF SUN-SPOTS FOR MAY, 1920.

No.	C. M. P.	Lat.	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1671	April 30.9	+11	27	α				α	α										
1673	27.0	+ 5	10	β															
1675	May 5.4	+14	8	β															
1676	7.5	− 4	7					α	α	α	α	α							
1677	8.8	− 7	23					βp	βp	βp	αp	βp	αp	αp	αp	x	x		
1678	3.0	+15	3						β										
1679	8.2	− 4	19							β	βf	βf	βf	αf					
1680	13.4	− 6	16							x	α	α	α	α	α	x	α	x	
1681	14.8	+18	16									x	βp	βp	βp	x	βp	x	
1682	9.7	−17	5										β						
1683	8.8	+14	22														αp		
1684	14.0	−13	—														x	x	
				3	—	—	—	3	4	4	4	5	5	4	3	3	5	3	—

No.	C. M. P.	Lat.	H	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1680	May 13.4	− 6	16	x															
1681	14.8	+18	16	x			βp												
1685	22.6	+23	10	x	βp	β	β	β		βp	αp								
1686	27.4	+ 8	29							α	αp	βp	βp	βp	βp	αp	αp	βp	αp
1687	27.8	− 8	10										β	αp	βf				
1688	23.3	+ 4	12											βf	βf				
1689	31.6	+14	16											x	βp	βp	βp	βp	βp
1690	25.2	−12	8													β	β	β	x
1691	25.9	+ 5	12															αp	Bf
1692	June 4.5	+15	31															x	βp
1693	May 29.9	+12	3																α
1694	30.9	+16	12																αp
				3	1	1	2	1	—	2	2	1	2	4	4	3	3	5	7

NOTES.

No. 1671 Return or revival of 1665.

No. 1680 Return of 1669. This is the last appearance of the great group of March 21.

No. 1686 This group on some days consisted of several spots in stream formation but all were of the same polarity. On one day a small spot of opposite polarity followed.

No. 1692 Return of 1683.

MAGNETIC CLASSIFICATION OF SUN-SPOTS FOR JUNE, 1920.

No.	C. M. P.	Lat.	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1686	May 27.4	+ 8	29	αp	αp													
1689	31.6	+14	16	αp	x													
1691	25.9	+ 5	12	x														
1692	June 4.5	+15	31	βp	βp	βp	βp	βp	βp	βp	αp	αp	αp					
1694	May 30.9	+16	12	βp	β	βp	βp	αp	x									
1695	June 6.3	− 5	14		βp	βp	βp	αp										
1696	May 31.2	+ 8	8		β	βf												
1697	June 9.4	−12	10					α	α									
1698	11.4	+14	32							βp	βp	βp	βp	βp	βp	βp	βp	
1699	11.7	+22	12								βf	αf						
1700	12.3	+18	19											βp	βf	βf	β	
1701	16.8	+11	—											x	x	x		
1702	14.6	+11	6													βf		
1703	20.5	− 9	23														x	
				5	6	4	3	4	3	2	3	3	2	3	3	4	3	—

No.	C. M. P.	Lat.	H	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1698	June 11.4	+14	32	αp	αp													
1700	12.3	+18	19	β	αf													
1703	20.5	− 9	23	αp	αp	α	α	αp	αp	αp	αp	αp	αp					
1704	22.7	− 8	27		αp	αp	αp	αp	αp	αp	αp	αp	αp	αp	x			
1705	18.4	+ 8	5					β	β									
1706	23.0	+ 6	6						αp									
1707	27.0	+15	23						x	γ	βγ	βγ	βγ	βγ	x		βγ	βγ
1708	23.9	−20	19								βp	β	βp	βp	x			
1709	July 1.5	+14	30										x	α	x		α	α
1710	3.4	−14	28														Bp	βp
				3	4	2	2	3	5	3	4	4	5	4	4	—	3	3

NOTES.

No. 1703 Return of 1690.

No. 1707 Return of 1694. No. 1707 was made up of three or four small spots. The polarities of the leading and following spots were both positive, and the main spot, of negative polarity, was between them in longitude and about two degrees north. It had the appearance of a bipolar group, abnormally inclined to the equator, followed by a unipolar spot.

PARALLAX NOTES

a. N. G. C. 4051. The spiral nebula N. G. C. 4051 is described by Curtis as "a fine, rather bright spiral 4′ x 2′. Very bright stellar nucleus. There are numerous almost stellar condensations. It is a two-branched spiral, and each branch is bifid." On the fifteen-minutes exposures taken at the 80-foot focus of the 60-inch reflector, the central part only is visible and in appearance its images are hardly different from the surrounding stars. From sixteen exposures I find a relative parallax of +0″.001 ±0″.005. From a discussion of the systematic errors of all directly determined parallaxes, we have recently derived the conclusion that the Mount Wilson parallaxes are 0″.002 too large, and since the reduction from relative to absolute parallax is +0″.002, we may use the relative Mount Wilson parallaxes as the final absolute values.

TABLE I

N. G. C.	π	p.e.
224	+0″.004	±0″.005
4051	+0 .001	±0 .005
5194	+0 .005	±0 .008

For three spirals, parallaxes have now been determined at this Observatory. The results are collected in Table I. From this we can only draw the conclusion that the parallaxes of these objects are too small to be derived by the parallax methods now in vogue.

b. BD +30° 3639. This is Campbell's hydrogen-envelope star. From sixteen exposures we have derived a parallax of +0″.005 ±0″.009. The nebulosity, however, is not quite symmetrical with respect to the central star, and plates not taken with very good seeing may vitiate the measures. The series of plates will therefore be increased until we have a set of extremely good plates and the present result must be taken as preliminary.

c. From twelve exposures of the beautiful planetary *N. G. C. 6543*, a preliminary parallax of +0″.041 ±0″.006 was derived.

Including BD +30° 3639, which resembles a planetary more than it does a typical Wolf-Rayet star, we have now finished the parallaxes of ten planetaries. The results are collected in Table II.

TABLE II

N.G.C.	π	p.e.	m
40	0″.000	±0″.003	11.6
2022	+0 .008	0 .004	14.2
2392	+0 .020	0 .003	10.0
6543	+0 .041	0 .006	11.3
6720	+0 .008	0 .005	14.7
6804	+0 .020	0 .003	13.4
6905	+0 .013	0 .002	14.5
7008	+0 .014	0 .004	12.8
7662	+0 .021	0 .004	12.9
BD+30° 3639	+0 .005	±0 .009	10.4

To derive a homogeneous system for the photographic magnitudes of the central stars, counts were made of the number of stars of equal and brighter magnitudes in as large an area as the plates would allow. Then with the help of Table IV of ***Publications of the Astronomical Laboratory at Groningen***, No. 27, the apparent photographic magnitudes m were derived. Using the formula

$$\overline{M} = 5 \log \overline{\pi} + 5 - 5 \log \overline{10^{-0.2m}},$$

which is based on the supposition of equal absolute magnitude, we find for the mean absolute magnitude of these ten central stars

$$\overline{M} = +8.5$$

d. From fourteen exposures a parallax of +0″.023 ±0″.006 was derived for W *Ursae Majoris.* For the same star Shapley derives +0″.020, while the Yerkes Observatory has published a value which (corrected for systematic error) is +0″.017 ±0″.010. The absolute parallax of this eclipsing variable may therefore be taken as +0″.020, which gives an absolute magnitude of +4.4 at maximum and +5.1 at minimum.

e. A Star of large proper motion near W Ursae Majoris. 10′.5 west and 2′.5 north of W *Ursae Majoris* a star was found with considerable proper motion. Its provisional photographic magnitude as derived by Mr. Seares is 14, while its color class is about *k*. The proper motion and parallax were derived, using the same comparison stars as for W *Ursae Majoris*. As these are all east of the star, the determination is only preliminary. On our plates, however, no stars are found west of the object in question. The results are

$$\mu = 0''.924, \text{ in } p = 238^\circ.4$$
$$\pi = +0''.030 \pm 0''.031$$

The star has been placed on the regular parallax program in order to derive a more trustworthy result. The position for 1900 is

$$\alpha = 9^h 35^m 27^s$$
$$\delta = +56^\circ 27'$$

A. VAN MAANEN.

NOTE ON STRÖMBERG'S METHOD OF DETERMINING MEAN ABSOLUTE MAGNITUDES

In this method[1] the true mean absolute magnitude of a group of stars is obtained by comparing the geometrical mean of their peculiar radial velocities with that of a certain function of their proper motions. All stars are included except those for which the peculiar velocity (or other quantity, as the case may be) is very small or zero. It is the purpose of this note to show how this limitation may be removed.

We have to take the arithmetical mean of the logarithms of the velocities. For those above some finite limit (say, for example, 1 km) no difficulty arises; but the logarithms of the few small values are negative and may be very large or even infinite.

Suppose that there were a great many such quantities uniformly distributed thru the interval from 0 to 1 with respect to the quantity itself, not its logarithm. Tho the logarithm of the limiting value 0 is infinite, it is easy to show that the mean of all the logarithms will be finite and fairly small. At the limit, when sums go over into integrals, this mean will be

$$\frac{\int_0^1 \log x \, dx}{\int_0^1 dx} = \frac{\left[x \log x - x\right]_0^1}{1} = -1$$

the logarithms being "natural logarithms."

Thus, *if a series of numbers are distributed uniformly and densely between 0 and 1, their geometric mean is 1/e, where e is the "base of logarithms."* Similarly the geometric mean of numbers uniformly distributed between 0 and n is n/e.

From this it follows that the cases previously excluded in Strömberg's method can be included by assuming that all the velocities, etc., below some convenient limit ought to be uniformly distributed between this limit and zero, and substituting for the logarithm of each of them the logarithm of the geometric mean for such a distribution, that is, the value

$$\log \text{limit} - \log e,$$

or, if the logarithms are ordinary ones to the base 10,

$$\log \text{limit} - 0.4343.$$

How high to take the limit of application of this process is a matter of judgment. It is probably well to make it high enough to include a fairly considerable number of observed values, provided that it is not extended so far as to include a region within which the distribution of the observed quantity departs seriously from uniformity.

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[1] *Contributions from the Mount Wilson Observatory*, No. 144; *Astrophysical Journal*, 47, 12, 1918

Princeton University Observatory. HENRY NORRIS RUSSELL.

NOTE ON THE USE OF THE GEOMETRICAL MEAN PARALLAX

In the preceding note Professor Russell has pointed out a method of including small values of radial velocities and proper-motion components in the computation of geometrical mean parallaxes according to the formulae in *Mount Wilson Contribution* No. 144. A similar method of dealing with these small quantities was actually employed in the publication cited, namely, that of placing the radial velocities or proper-motion components in a number of classes, and for each class substituting the arithmetical mean for the individual values before taking the logarithms. Thus all radial velocities smaller than 2 km., and all proper-motion components smaller than 0".010 were put equal to 1 km. and 0".005, respectively The difference between this method and that of Russell is slight, but the latter is probably to be preferred.

In this connection attention may be called to the fact that, if the proper motions are all very small, the geometrical-mean parallaxes are uncertain on account of the errors in the measurements. In the first place these errors are enhanced in the logarithms; and in the second place they are systematically affected by the circumstance that the arithmetical mean, disregarding the sign, of a series of very small *measured* quantities is systematically larger than the corresponding mean, corrected for observational errors, by a quantity that is of the order of magnitude of the average error in the measurements.

GUSTAF STRÖMBERG.

THE MAGNETIC POLARITY OF THE SUN-SPOT GROUP OF MARCH 21, 1920

The spot group which crossed the central meridian of the Sun on March 21, 1920, was the largest since the great group of August, 1917. Because of its connection with the aurora and magnetic storm of March 22, an account of its magnetic field may be of interest.

On December 26, 1919, spots were first observed in the region which was later to become the scene of great activity. These spots, which were then near the east limb, and south of the equator, developed in a very normal manner and by December 30th formed a small bipolar group with regular polarity. That is, the spots in the preceding part were like the south-seeking end of the compass needle, while the following members were of opposite polarity. This has been true of the great majority of groups in the southern hemisphere since the spot-minimum of 1913. Cloudy weather prevented further observations until January 4, 1920. By that time the group had changed greatly, the leading spot being quite large with a field strength of 3200 gausses at the center of its umbra. Its polarity was that of a south-seeking pole while all but two of the smaller spots, which followed, were of opposite polarity, ranging in field strength from 1000 to 2500 gausses.

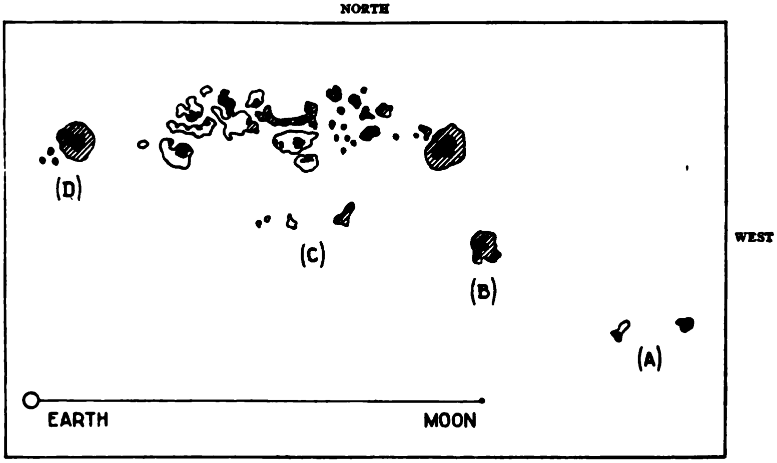

Figure 1. Sun-Spot Group of March, 1920.
(One-inch=100,000 miles).

At its next appearance no observations were made until January 23rd when it was beginning to show complex magnetic structure. The foremost member of the group was just south of the equator while the following spot was nine degrees south and twenty-two degrees east of the leader. The inclination of the group to the solar equator was, therefore, about twenty-five degrees. At its first appearance the group was nearly parallel to the equator but there is no evidence that the change came about by a rotation of the group. It had changed in character so much by the addition of new spots that none of the individual spots could be identified with certainty as previous members of the group. Altho the magnetic polarities were complex in their distribution thruout the following part of the group, the leading spots were regular. Large active groups often show complexities of this sort.

At its next return cloudy weather prevented observations except on one day. The group was then much smaller and more regular in its polarity.

At the fourth appearance it had developed again into a remarkable "stream." The reproduction is a tracing from a photograph on March 20th. The shaded spots correspond to a south-seeking pole, those of opposite polarity are shown in outline only. The large spot at the western end of the group and the eastern spot (D) had field strengths of 3000 gausses each. Near the center of the group is a spot in which regions of both polarities are shown. The field strength across the neutral lines was practically constant, about 1500 gausses, but the lines of force were there tangential to the Sun's surface. They can be considered as coming vertically out of the open area, turning and going down into the shaded regions. The small bipolar group (A), the unipolar spot (B), and the small bipolar group (C) are evidently not a part of the large group. This is verified by the hydrogen (Hα) and calcium (K_2) spectroheliograms. Because of its polarity one might also separate the extreme eastern spot (D) from the main group. The spectroheliograms partially substantiate this view tho not as strongly as for the other spots just mentioned. Disregarding these nearby spots the main group shows the regular bipolar characteristics but with some complications in its central part.

At the April return the large leading spot was all that remained of the group. It was then a stable spot with a field strength of 3100 gausses. The eastern spot (D) was fast dying out, having in April a mean field strength of only 1000 gausses. In May the large spot again returned but was then on the decline. It died out gradually; the last spots in that region were seen on May 16th. The group had been active for almost five months, passing the central meridian six times, a record of activity which is seldom equalled.

SETH B. NICHOLSON.

THE SPECTRUM OF R AQUARII AT MINIMUM BRIGHTNESS

The spectrum of the long-period variable star R *Aquarii* as it appeared in October and November, 1919, shortly before the time of maximum brightness, was described in the December issue of these PUBLICATIONS. In addition to the Md spectrum, which is to be expected in stars showing this type of variability, there appeared at that time several of the lines characteristic of gaseous nebulae. As the star grew brighter the nebular lines grew relatively less intense. Poor observing conditions prevented satisfactory observations at Mount Wilson in the short time that remained after maximum before the object was lost in the western sky. Such plates as were obtained, however, indicated that the nebular lines did not continue to weaken, but either remained of the same intensity or brightened slightly with respect to the Md spectrum.

It therefore appeared possible that the nebular lines might be independent of the variation in light: if this were true they would, of course, be relatively much stronger at the star's minimum brightness. Photographs recently secured show that this is actually the case, tho it is not certain that the nebular lines are wholly invariable in absolute intensities. Since conjunction with the Sun three plates have been secured with the 100-inch telescope and one-prism spectrograph as follows:

Date	Camera	Exposure	Magnitude
June 1, 1920	18-inch	19 min.	9.6 visual
July 6, 1920	18-inch	62 min.	10. visual
July 8, 1920	7-inch	100 min.	

The first plate shows N_1, N_2 and $H\beta$, with traces of λ4363 and $H\gamma$. The other two plates show these and additional lines. The following description refers to the plate of July 8th. Bright lines are the only features observable, continuous spectrum being absent or extremely weak.

BRIGHT LINES IN THE SPECTRUM OF R AQUARII, JULY 8, 1920

Wavelength	Intensity (estimated)	Identification
4102	1	$H\delta$
4340	5	$H\gamma$
4363	4	Nebular
4471	½	Helium
4571	2	Magnesium
4658	trace	Nebular
4861	9	$H\beta$
4959	9	Nebular
5007	16	Nebular

The lines λλ 4102, 4340, 4363, 4861, 4959, 5007 were reported as present on the plates of October and November, 1919. By comparison of the earlier with the later plates of the autumn series, weak emission lines at λλ 4471 and 4658 were noted, which appeared to vary in the same manner as the chief nebular lines. These doubtless correspond to two lines which are included in the above list. On the plate of July 8th λ 4658 is so weak that its reality as judged from this plate alone would be somewhat uncertain, but in view of its presence on the 1919 plates it is believed to represent a real line. Stronger exposures will soon be made which should show this line clearly. It is probably identical with the line given as 4658.2 IA in Wright's list of nebular lines[1].

λ4571 is almost surely of the same origin as a line which often develops great strength in Md spectra as minimum brightness is approached, becoming in some instances the strongest line in the whole photographic spectrum. It is probably due to magnesium under low temperature conditions.

It is interesting to note that a nebular line near the position of this magnesium line is included in Wright's list. Is it possible that these lines are identical? In any event it might be worth while to examine long exposures on the spectra of certain planetary nebulae to determine whether titanium oxide bands can be detected in the continuous spectrum.

The interpretation of the curious phenomena presented by R *Aquarii* is not yet clear. The fact that the nebular lines are roughly constant in intensity, while the Md spectrum varies thru a large range, suggests that the variable star and the source of the nebular lines are independent objects, yet numerous other observations seem to show rather definitely that they are closely connected. The actual association of the nebular lines with what must be considered as a low temperature spectrum would probably be a cause of surprise to many astrophysicists. It may be of significance in this connection that the high-excitation line λ 4686 has not been observed in R *Aquarii*.

When better understood this anomalous spectrum may prove to be an aid in the physical classification of the nebular lines

PAUL W. MERRILL.

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[1] *Publications of the Lick Observatory*, **13**, 1918.

OBSERVATION OF THE OCCULTATION OF THE STAR BD +17° 2028 BY JUPITER, 1920, JUNE 7

The following observations of the occultation of the ninth magnitude star BD +17° 2028 by *Jupiter*, on 1920, June 7, were secured with the 12-inch equatorial of the Lick Observatory. The chronometer times were noted and recorded by Miss Priscilla Fairfield. The observations were obtained by the writer.

The star was first seen, near the *following* limb of the planet, at 7^h38^m Pacific Standard Time. An approximate position-angle setting was made on the line joining the estimated center of the planet's disk and the star shortly before and again immediately after the occultation occurred. These position-angles are given below:

P. A. at 7^h44^m (before ingress) = 140° ±;
P. A. at 9^h12^m (after egress) = 256° ±.

The observations of the ingress follow:

Ingress	$7^h56^m00^s.5$ P. S. T. 56 50 .0 57 12 .5 57 20 .5
Certainly disappeared	58 04 .5
Invisibility confirmed	7 59 06 .0

The occultation was very gradual. It was extremely uncertain when the star had actually disappeared. The seeing was fairly unsteady, the image occasionally blurring. When the star appeared to be on the point of becoming extinguished, the time was taken. Four such times in all were recorded, as entered above under the word "ingress," but after each of the first three, the star was again visible. The inferior definition and the glare of the planet in close proximity to the relatively faint star are largely accountable for the uncertainty in the time of disappearance. The final time noted, $7^h57^m20^s.5$, is perhaps the most probable instant of the occurrence of the phenomenon.

The star was first observed upon egress at about $9^h7^m11^s$ P. S. T. It was obviously free of the planet's limb at $9^h7^m26^s.5$. That the precise moment of egress was witnessed is not likely, because of the lack of foreknowledge as to the position angle with respect to the center of *Jupiter* of the exact point of reappearance; and the brilliance of the planet, altho the seeing had improved perceptibly at emergence. The above time, namely $9^h7^m11^s$, is almost unquestionably too late by at least several seconds.

FREDERICK C. LEONARD.

The Occultation of Mars, 1920, July 22

The following observations of the immersion of the occultation of *Mars* by the Moon, on 1920, July 22, were obtained with the 12-inch refractor of the Lick Observatory. Because of the low altitude of the objects, the definition was poor, and this meteorological difficulty was enhanced by the proximity of clouds.

The immersion was at an end—*i. e.*, the Moon completely occulted the planet—at approximately $11^h 2^m 36\frac{1}{2}^s$ P. S. T. The dark limit of our satellite began to encroach upon the disk of *Mars* from $15\frac{1}{2}^s$ to $15\frac{3}{4}^s$ before this time—this interval of $15\frac{1}{2}^s \pm$ being determined by a stop-watch. The immersion commenced gradually and concluded in the same manner; at neither first nor second contact was it so sharp as in the case of a star. The non-instantaneity of the phenomenon may possibly be ascribed, partly to the refractive effect of the planet's atmosphere and partly to the disturbing influence of our atmosphere—the latter as imperfect seeing.

The emersion was not observable; it was due to occur below the horizon.

Frederick C. Leonard.

Personal Notes

Dr. Holger Thiele, during the past three years an assistant in the Lick Observatory, and earlier an observer in the Hamburg Observatory at Bergedorff, has been advanced to the grade of Assistant Astronomer. Dr. Thiele is the son of a former director of the Royal Observatory at Copenhagen.

Dr. Robert Trumpler, Martin Kellogg Fellow during the past year and for several years an assistant in the Allegheny Observatory, has been appointed an Assistant Astronomer in the Lick Observatory.

GENERAL NOTES

The Seattle Meeting of the Astronomical Society of the Pacific.—Seattle is more than 1400 miles from Pasadena and nearly 2000 miles from Flagstaff, yet delegates from the Lowell and the Mount Wilson Observatory as well as from the Lick, the Berkeley Students, and the Dominion Astrophysical Observatory were in attendance upon the meeting of our Society which was held in Seattle on June 17th-19th in conjunction with the meeting of the Pacific Division of the American Association for the Advancement of Science. Members of the Society from several of the colleges and universities in the Pacific area, and some from San Francisco and other places who are not connected with any institution were also present. We thus had a gathering which, if not very large, was thoroly representative and the meeting must be regarded as a very satisfactory one.

The Committee of Arrangements for the meeting of the Pacific Division (Professor S. L. Boothroyd of the University of Washington, being the local representative of our Society) generously aided by President Suzzalo and the faculty of the University of Washington, had made every possible provision for our comfort and entertainment. The halls of the University were placed at our disposal; automobiles were at hand at the close of the afternoon sessions on Thursday and Friday to take us out on the beautiful parkways about the city; luncheon was served both days at the Faculty Men's Club and at the cafeteria in the Home Economics building; and, on Friday evening, a complimentary dinner was given to all members of the Association.

General meetings in which all of the affiliated societies participated were held on the afternoons and evenings of the two days and a Research Conference was combined with the luncheons at the Faculty Men's Club. Professor A. O. Leuschner, Director of the Students' Observatory, Berkeley, and Dean of the Graduate School of the University of California, gave the opening address at this Conference, his topic being "Research in the College as contrasted with the University." Addresses were also made by delegates from the Universities of Washington and Oregon and the State College of Washington, and the Conference closed, on the second day, with a general discussion of the relation between research and instruction in our colleges and universities.

The meetings on Thursday afternoon took the form of two Symposia, one on Einstein's Theory of Relativity, the other on the Animal and Plant Resources of the North Pacific Ocean. On Thursday evening the Retiring President of the Division, Professor J. C. Merriam, gave an address on "The Research Spirit in Every-Day Affairs of the Average Man;" on Friday afternoon Professor R. W. Brock of the University of British Columbia, gave an illustrated address on "The Last Crusade under Allenby;" and on Friday evening Dr. Paul W. Merrill of the Mount Wilson Observatory, as substitute for Dr. C. E. St. John, whose name appeared upon the program but who was unable to attend, delivered the Sigma Xi-Phi Beta Kappa lecture which is a feature of the annual Commencement exercises of the University, speaking on the subject "The Chemistry of the Stars."

Many excursions were arranged for Saturday, including one to Victoria, B. C., where by the courtesy of Director Plaskett, opportunity was given for an inspection of the splendid 72-inch reflector before dark and for a view of the stars with it later on.

Speaking more specifically of the meeting of our own Society, we carried out in full the program announced in the June number of these PUBLICATIONS. The first session was held in Denny Hall on Thursday morning, June 17th, the American Physical Society, by invitation, meeting with us. President J. H. Moore presided and ten papers were read, several of them giving rise to interesting discussions. On Friday morning, in turn, we joined, by invitation, in the Meeting of the American Physical Society and several astronomers participated in the discussions of the papers presented. On Thursday afternoon we joined the mathematicians and physicists in the symposium on Relativity. Dr. Eric T. Bell of the University of Washington gave an excellent presentation of Einstein's theory from the mathematician's point of view. It had been arranged that Dr. St. John should discuss the astronomical bearings of the theory. In his enforced absence, Professor Boothroyd, who presided, called upon Dr. J. H. Moore, who made a brief but very clear statement of the three quantitative tests of the theory which are afforded by astronomical phenomena and pointed out the necessity for further observations before final judgment is pronounced. Professor E. P. Lewis of the University of California was also called upon and spoke effectively from the point of view of the physicist.

As already noted, Director J. S. Plaskett had generously invited the members of the Pacific Division to visit the observatory at Victoria on Saturday. Practically all the members of our Society who were in attendance and a number of other members of the Division accepted the invitation. When we landed, we found Director Plaskett and the members of the observatory staff awaiting us with automobiles and were taken for a drive about the city and thence to the observatory on Little Saanich Hill. Here we held the second regular session of our meeting, the attendance being quite as large as at Seattle. Afterwards, with Dr. and Mrs. Plaskett and the observatory staff as hosts, we enjoyed a picnic supper under the trees near the observatory in which we were joined by a number of friends of the institution from Victoria. We then had the privilege of examining in detail the mirror and mounting of the great reflector. In its optical and in its mechanical properties it seems to leave little to be desired, and that Dr. Plaskett and his small staff —four observers in all—are making effective use of it is amply demonstrated by the fact that in the first two years of its history they have accumulated several thousand excellent spectrograms and have discovered no less than one hundred spectroscopic binaries.

From every point of view, the Seattle-Victoria meeting of our Society must be accounted most successful and credit for this is due in large measure to Professor S. L. Boothroyd, Chairman of our Program Committee, and to Dr. J. S. Plaskett.

R. G. A.

A New Solar Observatory Station.—It is reported that Dr. C. G. Abbot, Director of the Astrophysical Observatory of the Smithsonian Institution, is establishing a station on the Haqua Hala mountains, near Wenden, Arizona. The plan is to get continuous first class measurements of the solar radiation for comparison with those being made at a similar station, which has been located at Calama, Chile. The observations at two such widely separated stations should provide a definite answer to the question as to whether or not the so-called "solar constant" is truly a constant.

National Committee of Canada for the International Astronomical Union.—It is announced that the personnel of this Committee is as follows:

Dr. OTTO KLOTZ, Director Dominion Observatory (Chairman).
Dr. J. S. PLASKETT, Director Dominion Astrophysical Observatory.
R. M. STEWART, Assistant Director Dominion Observatory.
Dr. R. E. DELURY, Research Astronomer Dominion Observatory.
Dr. F. HENROTEAU, Astronomer Dominion Observatory.
W. E. HARPER, Research Astronomer Dominion Astrophysical Observatory.
Dr. C. A. CHANT, Professor of Astronomy University of Toronto.
Dr. A. F. MILLER, Toronto.
C. C. SMITH, Meridian Circle, Dominion Observatory.
Dr. R. K. YOUNG, Astronomer Dominion Astrophysical Observatory.
Professor L V. KING, McGill University, Montreal.

MINUTES OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE WHITECOTTON HOTEL, BERKELEY, CALIFORNIA, ON JUNE 24, 1920, AT 6:00 P. M.

There were present President Moore and Directors Aitken, Costa, Black, Einarsson and Richardson.

The following were elected members of the Society:—

Mr. LINCOLN ELLSWORTH, of New York.
Mr. W. F. W. LENT, of Calgary, Manitoba.
Mr. W. P. TAYLOR, of Calgary, Manitoba.
Rev. ROSS MCDONALD, of Anaconda, Montana.
Dr. J. S. PLASKETT, of Victoria, B. C.
Prof. F. W. HANAWALT, of Tacoma, Wash.
Mr. C. N. TAYLOR, of Berkeley, Calif.
Mr. HALL MCALLISTER, of San Francisco, Calif.

The Chile Station of the Lick Observatory at Casill, Chile was elected as an Institutional member.

The Board by unanimous vote adopted a resolution extending to Dr. H. D. Curtis the Society's heartiest congratulations upon the opportunity for greater service to astronomy which has been opened to him by his appointment as Director of the Allegheny Observatory, and expressing their deepest appreciation of his generous and effective assistance in the work of the Society. He has served as member of the Board of Directors, as member of the Publication Committee, and as President, and has at all times stood ready to give freely of his time and energy to promote the interests of the Society. He takes with him the heartiest good wishes of all his associates here for large success in his new field of labor.

The following communication from a Life Member of the Society, who does not care to have his name mentioned at this time, was read by the Secretary:

> "A Life Member of the Astronomical Society of the Pacific who desires his name to be withheld, offers to the Society the sum of $1000 to defray the cost of six lectures to be given in San Francisco under the auspices of the Society during the ensuing winter season, 1920-21, free to the public, and presented in simple language.
>
> Inasmuch as an attempt is being made to collect $25,000 for the purpose of permanently endowing a fund to perpetuate a series of lectures each winter, the prospective donor would be glad, if the scheme eventually becomes operative, to have his name included among the list of donors and to consider the payment of $1000 as advanced for the special purpose of holding these lectures in anticipation of sufficient interest being taken to establish a fund."

Upon motion of Director Aitken, seconded by Director Costa, the following resolution was unanimously adopted:

> "Moved that the proffered gift be accepted with the Society's heartiest thanks to the generous donor, and on the conditions named by him; with the further proviso that, if the larger fund referred to by him is secured, a portion of the interest from it be set aside each year until the amount of the present gift ($1000) has been added to the principal."

On motion duly made and seconded, the President was instructed to appoint a committee to take up the detail of this matter and report at the next meeting.

The President announced that such committee would be appointed later[1].

Adjourned.

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[1] The President later appointed the following committee: Messrs. Benfield (Chairman), Aitken, Costa, Hodghead and Richardson.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN WHEELER HALL, BERKELEY, CALIFORNIA, ON JUNE 24, 1920, AT 8:15 P. M.

By courtesy of the authorities of the University of California this meeting was made a feature of the Summer Session of the current year. It was presided over by President Moore and the audience was one of the largest and most attentive gatherings which have been called out by the activities of our Society.

Dr. PAUL W. MERRILL, of the Mount Wilson Solar Observatory, who was the lecturer of the evening, had for his subject "*The Chemistry of the Stars*," an able and exhaustive paper.

Adjourned.

OFFICERS OF THE SOCIETY.

J. H. MOORE	*President*
BERNARD BENFIELD	*First Vice-President*
J. COSTA	*Second Vice-President*
A. L. BLACK	*Third Vice-President*
D. S. RICHARDSON	*Secretary and Treasurer*

Board of Directors—WM. H. CROCKER, C. S. CUSHING, D. S. RICHARDSON, J. COSTA, R. G. AITKEN, G. E. HALE, B. BENFIELD, W. W. CAMPBELL, A. L. BLACK, J. H. MOORE, STURLA EINARSSON.

Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
Finance Committee—C. S. CUSHING, W. H. CROCKER, A. H. MARKWART.
Library Committee—D. S. RICHARDSON, F. V. CORNISH, BERNARD BENFIELD.
Comet-Medal Committee—W. W. CAMPBELL, STURLA EINARSSON, H. M. JEFFERS.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

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PLATE VII. THE METEOR CRATER OF ARIZONA.

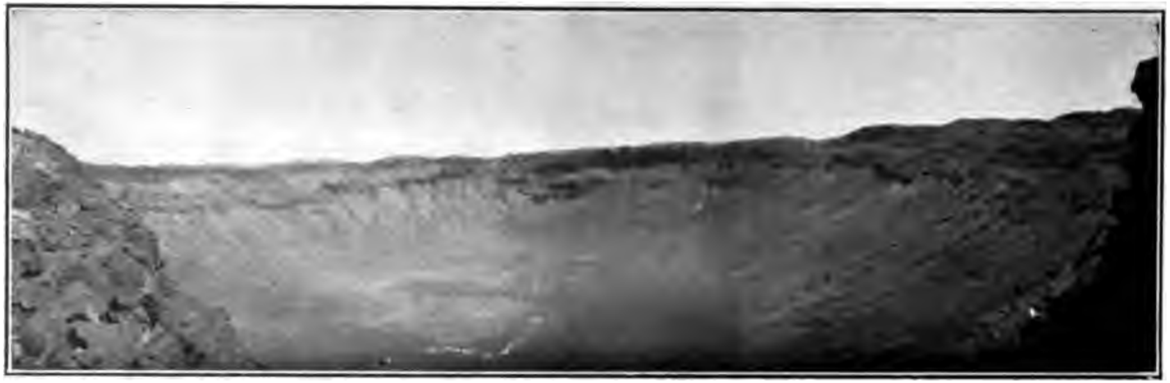

FIG. 1. VIEW LOOKING INTO AND ACROSS THE CRATER

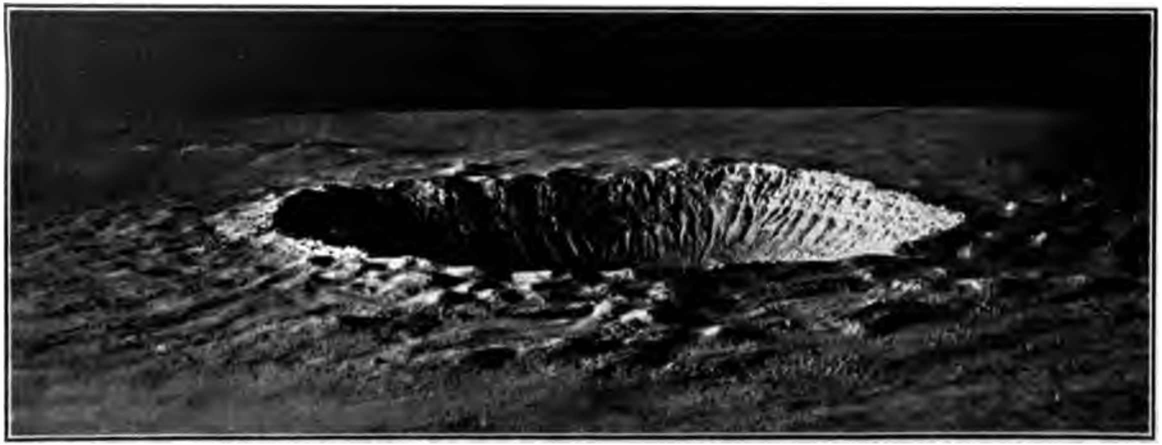

FIG. 2. IDEAL BIRD'S-EYE VIEW OF THE CRATER, FROM A MODEL MADE UNDER THE DIRECTION OF G. K. GILBERT

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXXII. San Francisco, California, October, 1920 No. 189

A RETROSPECTIVE VIEW OF THE ORIGIN OF METEOR CRATER, ARIZONA[1]

By George P. Merrill
Head Curator of Geology, U. S. National Museum

Recent conversation with Professor W. W. Campbell of the Lick Observatory on Mt. Hamilton, California, relative to the origin of the so-called Meteor Crater in Arizona, together with his paper in the *Publications of the Astronomical Society of the Pacific*[2], for April last, have led the present writer to review his own work on the subject[3] and to present again, in brief, the conclusions there reached, incidentally discussing what further evidence, one way or the other, may have come to his attention, together with reasons for any changes of view, should such there be. In so doing, it will be necessary to assume that the reader has seen the original paper as the subject is too large to be covered thoroly here. It must answer to state that the crater occurs in a region constituting an elevated and nearly level sandy plain, the floor of which is composed, in the main, of a buff colored arenaceous limestone, known as the Aubrey (Carboniferous) limestone, capped here and there by low flat-topped mesas of red sandstone and underlaid by a gray or faintly buff highly siliceous sandstone, also of Carboniferous age, and this in its turn by a yellow sandstone merging into red. The crater is some 4000 feet in diameter, and 600 feet in depth with a rim rising at its highest point 160 feet above the plain, this rim being composed of the lime- and sandstone beds mentioned, tilted at various degrees with the horizon and dipping away in all directions from a common center. Scattered over the surface in the immediate vicinity are enormous blocks of limestone, which have plainly been thrown out from the crater, and a great amount of disintegrated and finely pulverized sandstone from the underlying bed. The original depth of the crater cannot be told as it has become filled to its present level by material fallen from the inner walls, sands from the desert, and to a slight extent by beds of diatomaceous earth which must have originated in the temporary lake which at one time occupied the bottom (see Plate VII).

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[1] Published with the permission of the Secretary, Smith. Inst.

[2] Notes on the Problem of the Origin of the Lunar Craters, pp. 126-138.

[3] The Meteor Crater of Canon Diablo, Arizona, Its History, Origin and Associated Meteoric Irons, *Smithsonian Miscellaneous Collections*, Quarterly issue, Vol. 50, Pt. 4, 1908.

Two possible origins for this crater have been suggested. First, that it is due to explosive volcanic action; and second, to the impact of a giant meteor. Detailed investigations have been made, first by Mr. G. K. Gilbert; secondly by Messrs. Barringer and Tilghman and third, by the present writer. The conclusion reached by the last mentioned, with which alone this paper has to do, was rather in favor of an origin by impact. The facts mentioned below form the chief bases of this conclusion:

(1) Aside from the fact that there is here a crater, there are no evidences suggestive of volcanic action, no lava, and with one exception to be mentioned later, no ejectamenta that can be considered of a volcanic or solfataric character and that could not have been supplied by winds from distant volcanic centers.

(2) The rocks involved are wholly of a sedimentary nature.

(3) They are turned up at various angles in a manner which is highly suggestive of the displacement of material under the force of impact from without, altho it is evident that this condition might also be the result of explosive action from beneath.

(4) The ejected material on the slopes about the crater suggest that the agency, whatever it may have been, must have been sudden and of tremendous power, some of the ejected blocks weighing probably thousands of tons.

(5) There are no evidences of long continued activity. It would appear that the forces, whatever they may have been, acted suddenly, vigorously and abruptly ceased, altho it is possible that solfataric action might have continued for a considerable length of time in the one-time bottom of the crater, which is now hopelessly obscured.

(6) Considerable weight was attached to the presence both within and without the crater of thousands of tons of finely disintegrated material which plainly resulted from the shattering of the quartz grains in the sandstone, the particles being in a condition such as would result from a sudden explosion which produced not merely disintegration but the shattering of the individual grains themselves.

(7) In addition to the above, there were found both in borings and scattered about on the plain, masses of siliceous material in a highly altered condition which it was thought could be traced back to metamorphic influences such as would be induced by the enormous heat and pressure incidental to the downward plunge of a heavy meteoric body.

(8) Borings, made in extreme cases to the depth of 1100 feet below the present crater bottom, while showing no solid meteoric masses, did bring up from certain levels (450-650 ft.), pulverulent material which not merely reacted for nickel but which yielded at times small metallic particles which tests showed could not have come from the drill and which in their turn, yielded reactions for phosphorus, nickel and iron, indicative of schreibersite, a constituent of nearly all meteoric irons.

(9) Lastly, from the extreme depths to which the borings extended there were brought up cores of the deeper lying red and yellow sandstone, the granules of which were still intact with no signs of physical or chemical alteration, indicating that the sources active in the formation of the crater were limited to the overlying limestone and sandstone, and did not originate in the depths below.

In reviewing the subject, the writer has once more gone over his notes and materials and made additional chemical tests and finds no reason for changing the conclusions first reached which are based on the character of the evidence, as he understands it, quite regardless of any similarity between existing phenomena and the problematic craters of the Moon. The overlying limestone is wholly unaltered. The five hundred or more feet of sandstone in which the main body of the crater lies, as previously described, are shattered, and in reviewing the subject, a feature has come to light which the writer finds, to his astonishment, is not mentioned in the previous paper but which was considered at the time of the investigation and overlooked in the compilation of the final report. This detail of structure which is considered of importance is as follows:

The rocks around the rim are turned up at various angles from their original horizontal position as already mentioned. In one case particularly on the eastern rim, the underlying sandstone strata are even inverted (see Fig. 1). More than that, the sandstone beds so far as they can be seen—unfortunately they are greatly obscured by fallen and indrifted material—are shattered almost beyond recognition. As already stated, there are no indications whatever of intruded matter. In fact, it is certain there is none. The question at once arises, what, then, holds the beds in their present uplifted condition? Were this due to explosive action from beneath, they must, so soon as the forces ceased action, have fallen back into a horizontal position simply thru the action of gravity. This is precisely what has happened with explosive volcanic craters in other parts of Arizona and New Mexico with which this has been compared by those not sufficiently acquainted with details.[4] In the writer's opinion this condition of the beds can be accounted for only on the supposition that the sandstone has been driven back horizontally and the bed locally thickened by the impact of some large body which displaced the material once occupying the crater site throwing a portion out upon the surface and driving the remainder wedgelike back under the limestone. This, as stated, was noted at the time of the first observations but probably its full significance was not impressed upon me until attention was called to it by certain criticisms made by those advocating a volcanic hypothesis.

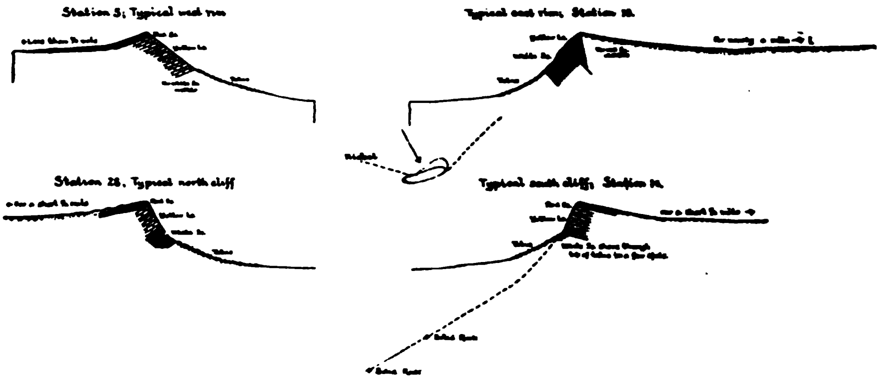
Station 5; Typical west rim
Typical east rim, Station
Station 28. Typical north cliff
Typical south cliff, Station

FIG. 1

As stated above, the writer has gone over once more his sections and repeated certain chemical tests. While no solid masses of meteoric material were found within the crater, there was brought up with the greatest regularity from the drill holes and from depths varying from 450-650 feet, disintegrated material reacting for constituents characteristic of meteorites. It is possible, of course, that a portion of this material might have been brought in by winds from the weathering of the blocks of meteoric iron which have been scattered in such quantity over the region northwest of the crater. This, however, is not deemed at all probable owing to the apparent regularity in depth below the surface of the stratum from which this material is derived.

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[4] The criticisms of J. F. Niermeyer (see accompanying bibliography) show an almost hopeless inability on his part to realize the true condition of affairs.

The writer's previously expressed view regarding the origin of the crater remains, then, unaltered and is to the effect that the crater form is due to impact from without. Whether the meteoric material found in the vicinity today is merely a coincidence or a part of the material instrumental in the production of the crater, is really immaterial, the present tilted position of the beds in themselves being regarded as conclusive evidence of an origin by some force which pressed downward crowding the friable sandstone back beneath the limestone as already described.

There is, however, one item of negative evidence, or at least of evidence of a doubtful character and of a considerable degree of importance which should be mentioned in this connection. I refer to the masses of what has been called "silica pumice" and "ghost sandstone" which have been found on the surface of the plain in the immediate vicinity and large masses of which constitute the immediate floor of the crater about the cabins on the slope. This material has been traced back to the Aubrey sandstone from which it is felt it was derived beyond question. But if so, what was the source of the heat sufficient to convert it into its present condition? It does not seem possible that it is due to solfataric agencies. If it were the heat of impact of a meteoric body, how does it happen that the material is now scattered over the surrounding surface? In the original paper, it was suggested that this might be explained as simply in the nature of a flareback. That the sandstone at the depth below the surface at which this action took place contained moisture, is, of course, probable. The heat incidental to impact, if sufficient to fuse the sandstone, must have converted this moisture instantly into steam with a tremendous explosive energy and this in its turn would result in throwing the altered material back upon the surface and, possibly, with it whatever meteoric material may have escaped volatilization by the tremendous heat developed. This is the only explanation that the writer could give at the time or which seems worthy of consideration today, tho he does not consider it quite satisfactory.

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SIR JOSEPH NORMAN LOCKYER—1836-1920

BY W. W. CAMPBELL

The recent death of Sir Norman Lockyer has deprived British science of an influential leader, and astronomy of a fruitful pioneer and contributor.

An index to Lockyer's influence upon the development of science, especially in the English-speaking countries, exists in the fact that he founded the weekly illustrated journal of science, *Nature*, and continued to serve as its leading editor as long as he lived. The semicentennial of the founding of this journal, the greatest of all weekly journals devoted to the advancement of science, was celebrated with world-wide felicitations a few months ago. Powerful appeals for the more generous support of scientific research were addressed to the British Government frequently by Lockyer, and not always in vain.

Lockyer's thoughts turned toward the study of the physics of the celestial bodies shortly following the discovery, in 1859, of certain of the fundamental principles of spectrum analysis; and the spectroscope, both in the laboratory and attached to telescopes, was his chief instrumental resource. A review of Lockyer's contributions to our knowledge of celestial bodies will reveal that he dealt effectively and in original ways with a great many important phases of astrophysics. His contributions began, in effect, in 1866, with a spectroscopic study of sun-spots. He noted that the spot spectrum is different in many details from that of the photosphere.

Up to the year 1868 the solar prominences had been observed only at times of total solar eclipse. That year Lockyer of England and Janssen of France independently and simultaneously reached the conclusion that the prominences could be observed and studied at the established observatories on any clear day, without the assistance of eclipse conditions. A high-dispersion spectrograph, with its widened slit in the focus of the image-forming telescope, would supply the necessary equipment. Both astronomers foresaw that the diffused light of the sky, which prevents the observation of the prominences with telescope and eye alone, would be so diluted by the high dispersion of the spectrograph that the prominence images, made up of a few monochromatic radiations, would be visible in the eye-piece. Janssen actually observed the prominences before Lockyer did, in August, 1866, but Lockyer's plans had been formed much earlier, and his spectrograph, designed and built with reference to prominence observations, was utilized successfully in October, 1868. Lockyer's description of the method and of the results was received by the Paris Academy of Sciences only a few minutes before Janssen's manuscript was handed to the Academy's secretary. The Academy awarded a joint gold medal to Lockyer and Janssen in recognition and honor of their important contributions.

Lockyer's interest in the observation of solar eclipses was intense and continuous. He organized and directed the work of many expeditions for the observation of eclipse phenomena in various parts of the world. Eclipse photographs, obtained by Lockyer and his leading assistants, were the first to distinguish between coronal and chromospheric bright lines. Up to the early '90's the strong hydrogen and calcium bright lines observed with spectroscopes directed to the edge of the eclipsed Sun were attributed (erroneously) to the corona as origin. Lockyer's expeditions established that these radiations are from the prominences and chromosphere, and that the radiations truly coronal do not include the hydrogen, calcium, and helium lines. The bright lines truly coronal are relatively faint.

Lockyer was able to establish that the prominences are merely upheavals of chromospheric matter, under the influence of forces then (and still) unknown. The deep stratum of the Sun known as the *chromosphere* received its name from him.

Lockyer showed that a bright orange line in the spectrum of the chromosphere, previously assigned by some observers to sodium, was in fact not in the position occupied by the well-known sodium pair of lines. He assigned the origin of this line to an unknown and hypothetical element, which he named *helium*. The history of helium investigation, dating from Lockyer's contribution, is one of the romances of physical science.

Lockyer and his assistants, several of whom are now distinguished contributors to astronomical science, were greatly concerned with variations in the laboratory spectra of the elements, as observed under different conditions of excitation: spectra resulting from the gas flame, the electric arc, the electric spark, under a variety of controlled conditions. They were able to show that certain conspicuous lines in the solar prominence spectrum were reproduced in the laboratory under the high temperature conditions of the electric spark, whereas many lines in the sun-spot spectra were observed in the laboratory spectra of the elements with the lower temperatures of the electric arc. This method of approaching the interpretation of solar and other stellar conditions has been further developed, with genius and great fruitfulness, by Lockyer's former chief assistant, Dr. Fowler.

Lockyer's well-known speculations on the "dissociation" of the chemical elements were suggested by the laboratory observations here described. According to the "dissociation" hypothesis, matter observed on the Earth or in certain low-temperature stars, in the form of recognized chemical elements, would, if transferred to stars of vastly higher temperatures, be transformed into matter simpler in molecular structure; and, vice versa, celestial bodies composed of the simpler chemical elements would, under lower temperature conditions, develop into matter more complex in molecular structure. Contributions by others to the knowledge of molecular structure in the past fifteen years have shown that Lockyer's speculations were based upon philosophic insight and vision. This statement does not imply that his conclusions as to molecular transformations were correct, but he was working close to the right track, and his ideas were highly valuable.

Studies made by Lockyer and his school of assistants as to the so-called "enhanced" lines of the elements have been exceedingly valuable in the interpretation of celestial spectra. When certain specified lines in the spectrum of one star are very prominent (enhanced), and these lines are relatively weak in the spectrum of another star, we may safely say, on the basis of Lockyer's contribution that the stellar temperature in the former case is relatively high, and in the latter case relatively low. It is possible that other factors than heat may also be in question.

More than three decades ago Lockyer put forth a "meteoritic hypothesis" of the origin of celestial bodies, namely: that the self-luminous celestial bodies have resulted from the combination of multitudes of meteoric bodies. The growth of the celestial bodies, by virtue of meteoric accretions, would be slow and long-continued. The coming together of meteoric masses would generate heat, under the influence of the collisions and gravitational condensations. Great gaseous and vaporous bodies known as the radiating nebulae, and stars of low temperature, would result. With the progress of time these bodies would pass thru a sequence of stellar types, as postulated in all existing hypotheses of stellar evolution. It can scarcely be said that the meteoritic hypothesis was received with marked favor in its early age, but its merits, as the possible representation of a great truth of nature, and as a rich suggestive influence, have increased in the estimation of astronomers with the passing of time. Its possible points of contact with the true story of stellar life are now recognized as numerous.

Lockyer's sequence of stellar evolution postulated that the stars progress with time from relatively low temperatures to the stage of maximum temperatures represented in the very blue stars, and thence decline to stellar states of low temperatures. Russell has in recent years been led to favor this same sequence of evolution, thru a study based chiefly upon stellar densities and stellar absolute magnitudes.

Careful consideration of Lockyer's contributions to astronomy must lead to his recognition as a bold yet philosophic speculator on the great problems of astrophysics. The impress of his observations and thought will be permanent in many salient particulars. He was not always right. The errors, to which every such active personality is liable, resulted chiefly from the overlooking of essential details, to which the genius of his mind was not strongly attracted. Those who, as students of astronomy, received their impetus in Lockyer's laboratory, have been attending to many of the details with great skill, and are extending the investigations into related and fruitful fields.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1920

BY MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME

Last Quarter....	Nov.	2, 11^h35^m P.M.	Last Quarter.....	Dec.	2, 8^h29^m A.M.
New Moon.....	"	10, 8 5 A.M.	New Moon......	"	10, 2 4 A.M.
First Quarter...	"	18, 12 13 P.M.	First Quarter....	"	18, 6 40 A.M.
Full Moon......	"	25, 5 42 P.M.	Full Moon........	"	25, 4 38 A.M.
			Last Quarter.....	"	31, 8 35 P.M.

The fourth and last eclipse of the year is *a partial eclipse of the Sun* on November 10th. The maximum obscuration is about three-fourths of the Sun's diameter. The region of visibility is eastern North America, the North Atlantic, and western Europe and Africa. The eclipse will be ended before sunrise on the western coast of the United States, but may be seen as a small partial eclipse in the early morning thruout the central and eastern parts of the country.

The Sun is at the winter solstice December 21st, 7^h17^m P. M., Pacific Time.

The Earth is in perihelion December 31st, 9 P. M., Pacific Time.

Mercury is an evening star on November 1st, having passed greatest east elongation on October 25th, but sets less than an hour after sunset so that the condition for visibility is not good. It reaches inferior conjunction and becomes a morning star on November 15th. It then moves out toward greatest west elongation reaching that point on December 3rd. It then rises more than an hour and one half before sunrise, and the interval remains more than an hour until after the middle of the month. Therefore during the last few days in November and the first half of December we have the best opportunity of the year for a morning view of *Mercury*.

Venus is an evening star setting about an hour and a half after sunset on November 1st; this interval increases quite rapidly so that by the end of December it is nearly three and one-half hours, and the planet has nearly arrived at its greatest east elongation, being 45° east of the Sun on December 31st. As *Venus* by this time is getting around to the part of its orbit nearer the Earth it will be markedly brighter than it was during the early summer, altho not nearly as bright as it will be in March after it has passed greatest east elongation.

Mars is still to be seen in the southwestern sky in the evening, setting at about half after eight, local mean time, with only a few minutes variation thru November and December. Both Sun and planet are moving eastward among the stars, the Sun gaining on the planet about 17°. This by itself would cause the planet to set earlier and earlier, but *Mars* moves 10° more northward than the Sun and this causes a later setting of the planet. These two conflicting elements combined with a rapid shift in the equation of time cause the planet to set at almost the same clock time thruout the two months. The actual distance of *Mars* from the Earth is still increasing rapidly, but at a slightly diminished rate. In consequence the planet is growing fainter, but even at the end of the year it will be nearly as bright as a standard first magnitude star.

Jupiter is a morning star drawing farther away from the *Sun* and rising earlier; on November 1st it rises at a little before 2 A. M. and on December 31st at about 10:30 P. M. It is still in the constellation *Leo*, and moves eastward 5° and southward 2° during the two months.

Saturn is east and south of *Jupiter*, rising at about half after two A. M. on November 1st and shortly before 11 P. M. on December 31st. It is also in *Leo* and moves 3° eastward and 1° southward during the period. *Jupiter* is therefore overtaking it and the bodies will come to conjunction with each other in 1921. On December 31st their distance apart is about 6°. The relative positions of the two planets will shift in quite an interesting way during 1921. Early in November the Earth passes thru the plane of *Saturn's* rings. For several years the southern face of the rings has been turned toward the Earth, now we see the northern face, but as we are nearly in the plane of the rings they look in the telescope like a mere straight line.

Uranus is in the southwestern sky in the evening, setting a little before 1 A. M. on November 1st, and at about 9 P. M. on December 31st, but on account of its faintness it is not visible to the naked eye for two hours or more before the time of setting. It is still in the constellation *Aquarius* and moves westward until November 11th and then eastward during the rest of the two months on a line a little north of its westward motion. It is still in the neighborhood of the fifth magnitude star *σ Aquarii* and is now approaching it from the west. At the end of December it will be about 1°30′ west of the star.

Neptune rises late in the evening. It is near the dividing line between *Cancer* and *Leo*.

POPULAR LECTURES ON PHASES OF THE NEW ASTRONOMY

As announced in the August number of these PUBLICATIONS (p. 255), the sum of $1000 has been given to the Astronomical Society of the Pacific by one of its Life Members, who wishes his name to be withheld, to provide for a series of six lectures to be delivered in San Francisco during the season 1920-21 under the auspices of the Society. It is stipulated that the lectures shall be free to the public and that they shall be presented in simple language.

The Committee appointed for the purpose has arranged for the following course. Each lecture will be independent of the others, but at the same time the subjects have been so selected that the series will give a fair presentation of the more important phases of what is sometimes called the New Astronomy. The spectroscope and the modern dry-plate, in conjunction with our powerful refracting and reflecting telescopes, permit the astronomer to analyze the light-waves which come to him from the Sun and from the stars and thus to gain knowledge of the chemical composition and the physical state of those bodies and to form some conception of the processes of their birth and evolution. It is the results of these studies, presented in non-technical language by men who are known as experts in their particular fields, and illustrated by experiments and by lantern slides, that these lectures aim to present to members of the Society and the people of San Francisco.

It is expected that the lectures, or abstracts from them, will be printed in the PUBLICATIONS of the Society.

1920

October 29—Professor E. P. Lewis, Professor of Physics, University of California. Subject: "The Spectroscope, Key to Atomic and Celestial Mysteries."

November 26—Dr. J. H. Moore, of the Lick Observatory. Subject: "Cipher Messages from the Stars."

December 28—Dr. G. E. Hale, Director of the Mount Wilson Observatory. Subject: "Sun-Spots as Magnets."

1921

January 28—Dr. E. C. Slipher, of the Lowell Observatory. Subject: "Photography of the Planets," (with special reference to Mars).

February 25—Dr. Harlow Shapley, of the Mount Wilson Observatory. Subject: "New Stars and Variable Stars."

March 25—Dr. W. W. Campbell, Director of the Lick Observatory. Subject: "The Life History of a Star."

LECTURE COMMITTEE.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE MOUNT WILSON PHOTOGRAPHIC MAP OF THE SUN-SPOT SPECTRUM

Some years ago the Mount Wilson Observatory issued a photographic map of the sun-spot spectrum, but the scale was small and the mode of preparation otherwise unsuitable for exhibiting the interesting phenomena caused by the magnetic field present in every spot. In order to show these phenomena as well as possible, a new map, covering the region λ 3900-λ 6600, has just been completed, and will be placed on sale at cost.

The negatives from which the map was made were taken in the second order of the 75-foot spectrograph used with the 150-foot tower telescope. They were afterwards enlarged to a scale of one centimeter to the angstrom, in order to show the separation of the lines caused by the magnetic field. The polarization phenomena characteristic of the Zeeman effect are rendered visible by the aid of a Nicol prism and compound quarter-wave plate mounted above the slit of the spectrograph. Thus in a normal triplet, such as λ 6173 or λ 6303, the red and violet *n*-components, which are elliptically polarized in opposite senses, are reflectively transmitted to successive strips of the quarter-wave plate.

Only a few of the numerous and complex phenomena shown on the map can be mentioned here:

(1) It will be observed that the separation of the components of lines affected by the field becomes gradually smaller, on the average, in passing from the red toward the violet end of the spectrum. This is due to the fact that, in harmony with Preston's law, the mean magnetic separation is proportional to the square of the wavelength.

(2) The telluric lines naturally show no magnetic effect, and the same is true of the great majority of the band lines, which represent compounds (including magnesium hydride, titanium oxide, and calcium hydride) rendered conspicuous in the spot by the reduced temperature.

(3) All types of magnetic separation found in the laboratory are undoubtedly present, but the intensity of the magnetic field, which does not often exceed 3500 gausses (for λ 6173), is usually insufficient to resolve lines having more than three or four components.

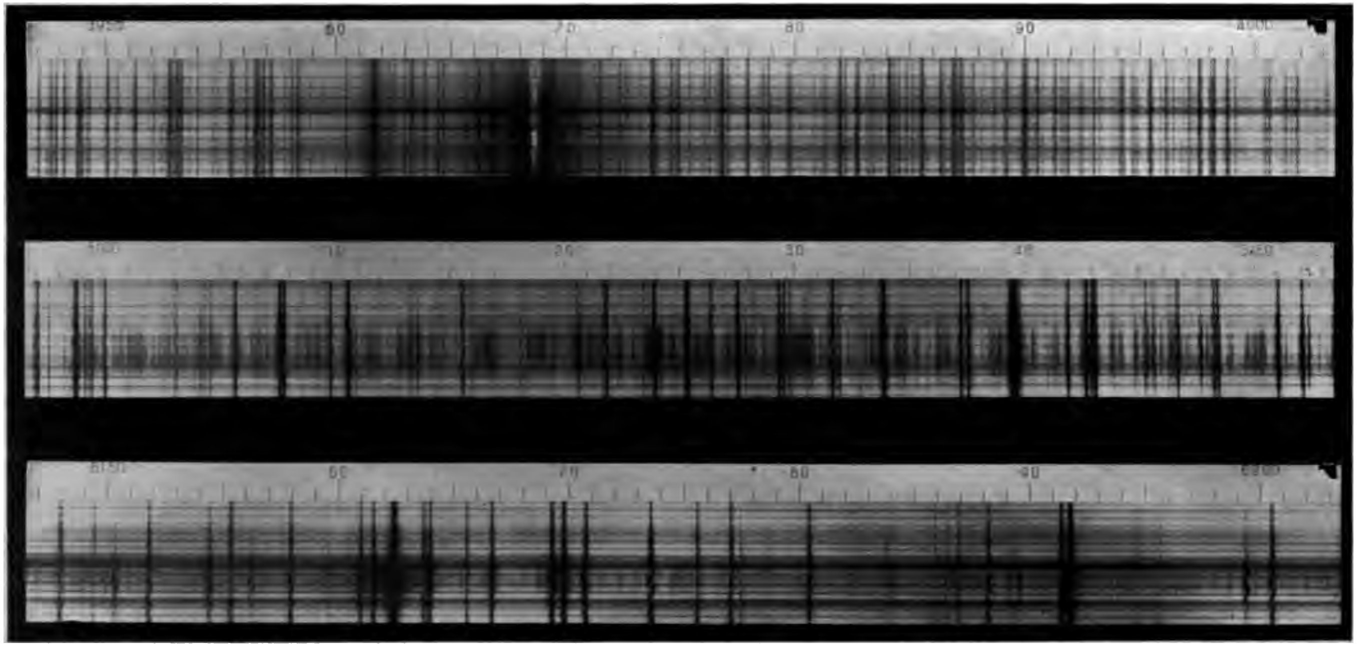

PLATE VIII. THREE SECTIONS OF THE MOUNT WILSON PHOTOGRAPHIC MAP OF THE SUN-SPOT SPECTRUM (Reduced Scale)

(4) The magnitude of the separation is not dependent solely upon the separation observed in the laboratory at unit field-strength, but also varies with the size of the spot and the level in the spot represented by the line in question. Thus high level lines, like H_2 and K_2, show very small displacements, while many lines corresponding to low levels, where the field-strength is much more intense, are widely separated.

(5) The polarization phenomena agree in general with those observed in the laboratory at similar angles with the lines of force, but there are certain notable exceptions that deserve careful study. One of these is illustrated by the behavior of the *p* (central) component of triplets like λ 6173, which may be seen on the map to show small displacements. These would seem to indicate that this line, instead of being single and plane polarized, as observed in the laboratory, consists in the spot of two components, each elliptically polarized in the sense opposite to that of the corresponding *n*-component.

(6) The intensities of the spot lines, which in many cases differ widely from their intensities in the solar spectrum, can be largely accounted for by the combined effects of level, magnetic field, and reduced temperature.

The interpretation of the spot spectrum is being worked out with the aid of laboratory experiments, and special provision has been made for the investigation of lines showing exceptional polarization phenomena.

GEORGE E. HALE,
FERDINAND ELLERMAN.

THE SPECTRUM OF NOVA CYGNI NO. 3

The announcement of the discovery of *Nova Cygni No. 3* reached the Lick Observatory on August 23rd. Observations of its spectrum were made on that night and have been continued at intervals of a few days to the present time.

The star was at its brightest on the evenings of the 23rd and 24th, when its magnitude was estimated at 2¼. The observers of Harvard College Observatory place the time of maximum more precisely on August 23rd, and its brightness as 1.9. After August 24th it fell away rapidly in intensity and is now of about the 6th magnitude and accordingly shines with but one-fortieth of its former brilliancy. The first spectroscopic observations were therefore made at about the epoch of maximum and have covered the first part of the waning of the star's light.

On August 23rd the spectrum was marked by dark bands due to hydrogen, calcium and the lines of the enhanced spectrum of iron, displaced, as is usual in the spectra of objects of this kind, toward the violet from their normal positions. "Undisplaced" fine lines of calcium and sodium were also present. In the part of the spectrum more refrangible than the green there was at that time little evidence of emission bands, but in the lower spectrum faint and rather narrow emission bands bordering the red edges of the dark bands were fairly conspicuous. The development of the spectrum has been marked by the formation and increase in intensity of the usual nova emission bands, by a general narrowing of the enhanced metallic dark lines, and by an increase in the displacement of the dark bands. This displacement, which on August 23rd was about −7A, increased as indicated in the following table to between two and three times that amount on August 31st. In this respect the behavior of the star reverses that of *Nova Geminorum* No. 2, which showed a progressive *decrease* in the displacement of the dark bands.

	DISPLACEMENT IN ANGSTROMS			
DATE	H_β	H_γ	H_δ	K
1920 Aug. 23..............	− 7.8	− 7.0	− 7.0	−6.8
1920 Aug. 24..............	−11.1	−10.3	− 9.1	−8.0
1920 Aug. 31..............	−22.	−16.	−22	.....
1920 Sept. 5..............	−23.	−14	......	.....

The measures for the first two dates are reliable, but the others are to be regarded only as provisional, because the lines in question are involved with other details of the spectrum. The dark hydrogen lines are now multiple and the displacement of the dark metallic lines corresponds approximately with that component of the hydrogen doublet which is least displaced. It seems doubtful whether the agreement is exact, but a definite statement in this regard can not be made in advance of a more complete examination of the plates.[1] The hydrogen emission bands show well defined minima corresponding more or less closely with the normal positions of the lines.

Displacements of the fine sodium and calcium lines. Fine lines at H, K, and D are recorded on all plates of suitable exposure. The D lines were photographed on one occasion with a dispersion of three prisms. They are very strong and, tho of substantial breadth, are sharply defined and exhibit the displacements set forth in the first line of the table. The corresponding quantities for the H and K calcium lines follow them.

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[1] FOOTNOTE.—See the following note.

DATE	D_1	D_2	H	K	MEAN	RAD. VEL.
1920 Aug. 24	−.29A	−.26A	......	......	−.275A	−14.0 km.
1920 Aug. 23	......	......	−.17A	− 21A	....	....
1920 Aug. 24	......	......	−.17A	−.16	....	....
1920 Aug. 31	......	......	(−.56)	−.16	....	....
1920 Sept. 5	......	......	−.37	−.28	−.22	−16.7

The measured displacement of H on August 31st has not been used in forming the mean. The mean of the two sets of velocities determined from the calcium and sodium lines—15.3 km. per second corresponds very well with 16.7 km., the component of the solar motion in the direction of the nova.

A striking feature of the spectrum is the extraordinary strength of the radiation of the lower members of the Balmer series, particularly Hα. The latter band lends a strong orange tinge to the telescopic image of the star. When the spectrum is photographed with a panchromatic plate this band is many times as intense as any other feature of the record. The fall in intensity of the Balmer series with decreasing wave-length is extremely rapid and appears to be uniform. It requires roughly fifty or a hundred times the exposure given to Hα to record a comparable impression of Hδ.

Speaking generally, the spectrum of the nova has, up to the present, followed what we have come to regard as the normal course of development. W. H. WRIGHT.

Mount Hamilton, September 16, 1920.

FURTHER NOTE ON THE SPECTRUM OF NOVA CYGNI

Recent plates, secured with somewhat greater dispersion, determine more clearly the nature of the multiple hydrogen absorption lines referred to in the preceding note. There are now at least five and probably six absorption bands, displaced by different amounts toward the violet from the normal positions of the hydrogen lines. The displacements are recorded in the following table, based on plates of September 17th and 18th, which give substantially identical displacements. The first column of the table designates the several components by letter. Under each number of the Balmer series considered are given the displacements of the components, their intensities and the quantity $10^4\kappa$ where κ is $\Delta\lambda/\lambda$, that is, the displacement divided by the normal wave-length of the hydrogen line in question. The proportionality of displacement to wave-length, within the limits considered, is very well indicated by the constancy of κ for any particular component.

DISPLACEMENTS OF DARK HYDROGEN LINES

Line / Component	Hβ			Hγ			Hδ			Mean
	Δλ	i	$10^4\kappa$	Δλ	i	$10^4\kappa$	Δλ	i	$10^4\kappa$	$10^4\kappa$
a	......	..	......	−11.6	3	−26.6	−10.8	5	−26.4	−26.5
b	......	..	......	−13.0	4	−30.0	−12.4	5	−30.0	−30.0
c	−17.1	2	−35.2	−15.6	5	−35.9	−14.8	5	−36.0	−35.9
d	......	..	......	−18.6±	1	−43.	−18.4±	1	−45.	−44.
e	−25.3	3	−51.5	−22.5	3	−51.8	−21.4	2	−51.9	−51.8
f	−29.2	2	−60.1	−25.8	1	−59.6	−24.5±	1	−59.5	−59.7

Components "a" and "b," which are separated from each other by only 1½ angstroms, blend at Hβ, and are barely resolved for the systems Hγ and Hδ. While there is little question of the duplicity, the measurement of these components may be somewhat inexact because of their closeness. There is perhaps some uncertainty with respect to component "d," which is faint and is not recorded so definitely as the others, but it is probably present, and may be double.

The displacement of the metallic dark line spectrum as determined by some of the stronger lines is as follows, the symbol κ having the same significance as before:

Normal λ	Element	Displacement	$10^4\kappa$
4233.3	Fe	−11.2A	−26.4
4395.2	Ti	−11.6	−26.3
4549.7	Fe-Ti	−12.4	−27.3
5018.6	Fe	−13.8	−27.5
		Mean	−26.9

The value of κ is therefore essentially in agreement with that corresponding to component "a" of the hydrogen series, that is, the metallic dark line spectrum agrees in position with the least displaced set of hydrogen dark lines.

The two strong lines to the violet of Hδ, which were so conspicuous in the spectrum of *Nova Aquilae* No. 3, and have been ascribed by Baxandall to the enhanced nitrogen lines at 4097 and 4103 A, are strongly impressed on a plate taken on September 21st. They are less displaced than in the spectrum of *Nova Aquilae*.

September 22, 1920. W. H. WRIGHT.

THE SPECTRUM OF NOVA CYGNI 1920

Observations of the spectrum of *Nova Cygni* were secured on August 22nd and successive nights up to September 3rd with the exception of August 24th when clouds prevented us from obtaining photographs. The maximum brightness of the star seems to have been reached during the night of August 23-24 when the magnitude was estimated at about 1.9.

The earliest spectrum of the star showed strong absorption lines of hydrogen displaced 6 angstrom units toward the violet and a number of fainter lines most of which could be identified with enhanced lines of iron and other elements. The spectrum bore many resemblances to that of *α Cygni* and was classified as A2. Helium probably was not present, altho a faint line near the displaced position of λ 4026 might perhaps be identified with it. It is more likely, however, to be due to enhanced titanium. H and K show narrow absorption lines from which the radial velocity of the star may be determined.

A faint brightening of the spectrum on the red side of the hydrogen absorption lines was observed on August 23rd, and on August 25th bright hydrogen bands were unmistakable. These became steadily stronger and bright bands due to the more prominent enhanced lines appeared thruout the spectrum. The absorption lines grew wider and more diffuse on successive dates and measurements were difficult. By August 27th the spectrum presented a definite appearance of bright bands interspersed with broad absorption lines superposed on a fairly strong continuous spectrum. The bright bands began to show the structure characteristic of most novae, with two maxima at the sides and a broad faint absorption band between. On September 4th it was possible to measure two components of the absorption lines of hydrogen.

The displacements of the absorption lines show very remarkable changes, a great increase taking place between the nights of August 23rd and 25th. The following summary shows the displacements of the hydrogen and the metallic lines for the dates of observation:

	Hydrogen	Metallic Lines
August 22	−6	−6.1
August 23	7	6.7
August 25	13	11.8
August 26	15	12.3
August 27	16	13.5
August 29	17	11.5
August 30	18±	11.7
August 31	17	11.8
Sept. 1	18	12.5
Sept. 4	−22, −15	11.4

The difference between the values for hydrogen and the other lines is evidently due in large part to the widening of the hydrogen lines toward the violet and the formation of the second component which was measured on September 4th. The strong enhanced lines at λ 4924 and 5018 behave very much like those of hydrogen in this respect and give values in good agreement with the latter. It is of interest to note that the minimum displacement in the case of this star as in that of *Nova Aquilae* of 1918 agrees fairly well with the maximum of light and increases rapidly when the star begins to decline in light.

The radial velocity of *Nova Cygni* as determined from the H and K lines on 15 spectrograms is −18 km. The component of the solar motion in the direction of the star is 18 km., thus indicating that the star has no appreciable velocity relative to the stars in general.

W. S. Adams,
A. H. Joy.

Two Stars of Spectral Class R with Large Radial Velocities

The number of stars known to belong to spectral Class R is small compared with that for almost any other type and consequently their average radial velocity would be greatly affected by a few abnormally high values. Accordingly it is of interest to call attention to two stars of this class whose radial velocities reduced to the Sun are exceptional. They are:

Name	Mag.	α 1920	δ 1920	velocity	No. of plates
BD+23° 123	8.3	$0^h 50^m.0$	+23°38′	−242 km./sec.	2
BD+20 5071	8.7	22 0 .6	+20 40	−416 km./sec.	2

These velocities have been derived from some of the best and most characteristic lines for this class of spectrum, assuming the wavelengths derived by Rufus[1] but they should be considered as approximations only. So far as the writer knows no velocity has been published previously for the first star.

BD+20° 5071 was observed by Rufus, who refers to difficulties in treating the measures he made. From three plates he deduced −49 km. sec. as the radial velocity reduced to the Sun. The writer feels that the larger value (−416 km. sec.) must be close to the true value for the following reasons; (*a*) it seems to give the best coincidence of lines when this star is compared with others on the Hartmann spectro-comparator, (*b*) it gives a better agreement between the lines of this and other Class R stars in character and intensity as given by Rufus, especially in the case of the stronger lines, (*c*) it is confirmed by the velocity (−420 km. sec.) given by the H and K lines of calcium on a spectrogram of this star taken with a focal plane spectrograph of low dispersion.

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[1] *Publ. of the Observatory, Univ. of Mich.*, **2**, 103, 1915.

It should be noted that in the finer details of the spectrum of BD+20° 5071 there are marked differences from other Class R stars and that this fact makes the radial velocity treatment of this star difficult.

These two stars stand out as exceptional in their radial velocities among more than twenty others which have been observed. Unless others are found perhaps they should not be considered in connection with the average radial velocity for the class. Certainly if considered among twenty or so others whose velocities are moderate they will considerably change the average.

R. F. SANFORD.

SUMMARY OF MOUNT WILSON MAGNETIC OBSERVATIONS OF SUN-SPOTS FOR JULY AND AUGUST, 1920

Foggy weather prevented observations with the spectroheliograph on August 24th, 25th, and 26th so that there is some uncertainty in the classification of the *a* groups on those days. No. 1734 was most likely *ap* on both days. No. 1735, which was a negative spot in the northern hemisphere may have been *af*.

MAGNETIC CLASSIFICATION OF SUN-SPOTS FOR JULY, 1920.

No.	C. M. P.	Lat.	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1707	June 27.0	+15°	23	βγ	x														
1709	July 1.5	+14	30	αp	αp	αp	αp	αp	αp	αp									
1710	3.4	−14	30	βp	βp	βp	βp	βp	βp	αp	αp	αp							
1711	9.5	+17	18				β	β	βp	βp	βf	βp	βp	β	βp	β	αp		
1712	3.8	− 6	8						βp										
1713	13.6	− 4	16								αp	βp	αp	α	α	α			
1714	20.8	−14	9															x	
				3	3	2	3	3	4	3	3	3	2	2	2	2	1	1	

No.	C. M. P.	Lat.	H	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1714	July 20.8	−14°	9	α	α	α	α	α	x	x									
1715	July 13.6	− 5	7		αp	βp	x												
1716	22.8	+12	26		αp	αp	α	α	α	α	α	α	α	α	α	α	x		
1717	22.8	+ 8	11		αp	αp	α	β	αp	αp									
1718	17.3	+ 8	7					α	x										
1719	22.6	+14	3						βp	α									
1720	28.5	+14	23							x	α	α	α	α	α	α	α	α	α
1721	24.2	+ 8	4								α	βγ	αp	αp	x	α			
1722	30.6	−14	24										α	α	αp	αp	αp	αp	αp
1723	Aug. 1.6	− 6	4												x	β	βp		
				1	4	4	4	4	5	5	3	3	4	4	5	5	4	2	2

NOTES.

No. 1715 A revival of No. 1713.

No. 1716 A return of No. 1707. No. 1716 was not a typical α group until July 24. Before that date the group consisted of a rather large positive spot followed by smaller spots, which were also positive. It is very unusual for following companions to have the same polarity as the leader when they are as far distant as in this group. No. 1707 was also peculiar in polarity distribution.

No. 1720 A return of No. 1709.

No. 1721 On July 23rd a single small negative spot was observed which was apparently in the center of the surrounding calcium flocculi. On July 24th two small preceding positive spots had appeared and also a very small positive spot due north of the negative spot.

No. 1722 A return of No. 1710.

MAGNETIC CLASSIFICATION OF SUN-SPOTS FOR AUGUST, 1920.

No.	C. M. P.	Lat.	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1720	July 28.5	+14°	23	α	βp	x													
1722	30.6	−14	24	αp	αp	αp	αp	x											
1724	Aug. 5.6	+13	7		βp	βp													
1725	5.0	+19	4			αp													
1726	2.8	+13	7					βp	βp	αp									
1727	4.5	−10	5					βp											
1728	1.1	+13	4						β										
1729	5.6	+13	5							α									
1730	15.1	+13	22									x	x	βf	βf	βf	βf	βf	
1731	17.6	−22	27												αp	αp	βp	βp	
1732	18.1	−12	9												x	αf	βf	β	
1733	18.8	+12	15													α	α	α	
				2	3	4	1	3	2	2	0	1	1	1	3	4	4	4	

No.	C. M. P.	Lat.	H	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1730	Aug. 15.1	+13°	22	βf	α														
1731	17.6	−22	27	βp	αp	βp	βp	βp	αp	αp	αp								
1732	18.1	−12	9	αf															
1733	18.8	+12	15	αp	αp	αp	α	α	α	α									
1734	27.3	+11	23						x	αp	αp	x	α	α	αp				
1735	28.2	+16	4										α	x					
1736	30.2	− 2	3											γ					
1737	Sept. 2.4	−14	30														βp	βp	βp
				4	3	2	2	2	3	3	2	1	2	3	1	0	1	1	1

NOTES.

No. 1729 A revival of No. 1724.

No. 1732 Altho no spots were seen in this region after August 16th, bright calcium flocculi were present until the region passed over the limb on August 23rd.

No. 1733 A return of No. 1716.

No. 1734 This was a regular unipolar group, the principal spot, which was positive, being accompanied by one or two small spots of the same polarity. On August 26th and 27th two small positive spots appeared three or four degrees following the main spot. On these days it resembled No. 1716 in this respect.

No. 1735 This was a small negative spot on August 25th. On August 26th there were some faint markings present which were too small for polarity determinations.

No. 1736 This group consisted of a very small negative spot, about two degrees north and half a degree preceding a very small positive spot. The inclination to the equator was so abnormal that it was not classed as a bipolar group.

MERIDIAN CIRCLE OBSERVATIONS OF NEW STARS

NOVA CYGNI 1920

Epoch	R. A.	1920.0	Decl.	Obs.	Mag.
1920.67	$19^h56^m24^s.647$	+53°	24′1″.06	4W	2 to 4
Precess. 1920	$+1^s.5005$		+9″.752	....	....

This position reduced to the epoch 1875.0 gives $19^h55^m17^s.1$ +53°16′44″. There is a fifteenth magnitude star on the Wolf-Palisa photographs, preceding $4^s.1$, and 8″ north. The date of the photograph is 1905, and a proper motion of 2″.5 for the faint star would be required to bring it into coincidence with the position of the nova. The measurement of the photograph position of the faint star was made by Dr. Thiele.

Nova Aquilae No. 3

The following positions for three successive years have been reduced to 1920.0

NOVA AQUILAE NO. 3

Epoch	R. A.	1920.0	Decl.	Obs.	Mag.
1918.56	$18^h44^m49^s.663$	+0°29′	37″.85	8 E	3 to 4
1918.58	49 .640	......	37 .95	8 W	0 to 4
1919.61	49 .642	......	38 .05	4 W	6.7
1920.58	49 .637	......	37 .84	4 W	8.8
Precess. 1920	$+3^s.0618$	......	+3″.897	...	....

The observations of 1919 and 1920 have been corrected for magnitude equation in right ascension. There is no indication of sensible proper motion.

R. H. TUCKER.

September 7, 1920.

GENERAL NOTES

A New Observatory.—A well-equipped observatory, presented to the Case School of Applied Science at Cleveland, Ohio, by Mr. Worcester R. Warner and Mr. Ambrose Swasey, founders of The Warner & Swasey Company, is approaching completion. The dedication will occur on October 12th. Director Campbell, of the Lick Observatory, will deliver the address, with subject, "The Daily Influences of Astronomy."

The Warner & Swasey Observatory is located on a small hill near Euclid Avenue, in the eastern residential section of Cleveland. The instrumental equipment consists of a Warner & Swasey-Brashear equatorial, three transit instruments, zenith instrument, and a chronograph. The lower floor of the Observatory building will contain a library and the living quarters of the astronomer.

One Hundred Spectroscopic Binaries.—Number 10, Volume 1, of the *Publications of the Dominion Astrophysical Observatory*, contains a list of the first one hundred spectroscopic binaries discovered at Victoria since work began there in May, 1918. The variable velocity of these stars was detected by the members of the staff, J. S. Plaskett, W. E. Harper, R. K. Young and H. H. Plaskett, in the course of the regular program of radial velocity measures of 772 stars, between the 5th and 10th magnitudes, selected in cooperation with the Mount Wilson Observatory, from Boss's *Preliminary General Catalogue.*

Of the 576 stars so far observed one hundred have shown variable velocity in the line of sight, or about the same proportion of one in six which has been found for the brighter stars. That 98% of these binaries should belong to spectral classes B, A and F and only 1% respectively to classes G and K, with none of class M, is due in large part to the short period of time (less than two years) covered by their observations and to the fact that the one-prism dispersion used by them is not sufficient to detect small variations in velocity.

Whether the apparent decrease in the number of binaries of spectral classes G, K and M for the fainter stars as compared with the corresponding numbers given in Campbell's *Second Catalogue of Spectroscopic Binaries* (for the brighter stars) is all attributable to the causes mentioned will remain for future observation to determine.

Full data of observation concerning these one hundred new spectroscopic binaries are given in the published table and will be of the greatest value to future observers who wish to investigate further any of these stars. J. H. M.

Dr. George E. Hale has been elected one of the twelve foreign members of Societa Italiana delle Scienzie, in succession to the late Lord Rayleigh.

Dr. W. W. Campbell was recently elected an Honorary Foreign Fellow of the Royal Society of Edinburgh.

Professor Benjamin Boss, Director of the Dudley Observatory Albany, New York, is making a series of tests of "seeing" conditions in the coast range of California and the southwestern states, for the Department of Meridian Astronomy of the Carnegie Institution of Washington. In this connection Professor Boss has spent some time at Mount Wilson and Mount Hamilton.

Dr. Edison Pettit, since 1918 Assistant in Solar Physics in the Yerkes Observatory, has been appointed a member of the staff of the Mount Wilson Observatory. Dr. Pettit received the degree of Ph. D. this last summer at the University of Chicago.

Elements of Borrelly's Periodic Comet, 1905 II.—The following elliptic elements of Borrelly's Comet, 1905 II, have been computed on the basis of M. P. Chofardet's observations at Besançon on October 7, 1918, December 6, 1918, and February 4, 1919, as printed in the *Astronomical Journal* for July 19, 1920.

E = 1918, Dec. 6.3802 G. M. T.
$M = 2^\circ 47' 12''.18$
$\omega = 352\ 23\ 32\ .45$
$\pi = 69\ 20\ 34\ .74$
$\Omega = 76\ 57\ \ 2\ .29$
$i = 30\ 29\ 13\ .54$
$\log e = 9.788886$
$\log a = 0.559350$
$\log q = 0.144792$
$\mu = 514''.023$

FRANK E. SEAGRAVE,

Boston, September 7, 1920.

Death of Eric Doolittle.—It is with the deepest regret that we record the death of Dr. Eric Doolittle, Director of the Flower Observatory, of the University of Pennsylvania, on Tuesday, September 21st. An account of his valuable contributions to astronomy will be printed in our December issue.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD AT THE LICK OBSERVATORY, MOUNT HAMILTON, ON AUGUST 20, 1920.

There was no set scientific program for this meeting. It partook of the nature of an excursion to the Lick Observatory and a delightful outing. Director Campbell and staff, ably seconded by the ladies of Mount Hamilton, had not only fixed a special date for the reception of the Society, but provided a bountiful picnic luncheon for about thirty-five hungry people who reached the summit at six P. M. The memory of that luncheon and the kindly hospitality which accompanied it will not soon fade from the recollection of those who were so fortunate as to be present.

After eating, the observatory was thrown wide open to the happy visitors. The great thirty-six-inch telescope was swung into position and object after object of transcendent beauty was snatched from the azure vault. Nothing escaped. Nebulae, star clusters, timid binaries and blazing suns came one by one from their hiding places at the beckon of the magic glass. The Moon, which was in excellent position for observation, was especially kind and revealed every crack and crevice of her pock-marked countenance. Never before have the members of the Society so revelled in the opportunity to see the wonders of the sky, and Doctors Campbell, Aitken, Moore, Wright, Tucker, Trumpler, Thiele and all the rest stood by with infinite patience, explaining it all to the wondering laymen. At ten o'clock the autos dropped away through the scented canyons to the valley below, carrying a party of contented and very grateful excursionists to their distant homes.

The following were among the members and guests who were present on this occasion:

Mr. A. L. BLACK,
Mr. BERNARD BENFIELD,
Miss CECILE BENFIELD,
Miss SALLIE BENFIELD,
Mr. EDWARD JESURUN,
Prof. and Mrs. EARLLE G. LINSLEY,
Mr. and Mrs. E. M. KNOLLIN,
Mr. E. W. PUTNAM and son,
Mr. and Mrs. EDWARD COUNIHAN,
Miss ADA CLEMENT,
Mrs. D. A. HODGHEAD,
Miss LILLIAN HODGHEAD,
Mr. and Mrs. KIMBALL G. EASTON,
Mr. and Mrs. B. A. BAIRD,
Mr. and Mrs. A. SIEBRECHT,
Mrs. J. C. WENDT,
Mrs. N. A. HAWKINS,
Mr. HENRY U. BRANDENSTEIN,
Mr. A. MACK,
Mr. CHARLES S. MABERY of the Case School of Applied Science.
Mr. and Mrs. D. S. RICHARDSON and son.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT LICK OBSERVATORY, MOUNT HAMILTON, ON AUGUST 20, 1920, AT 9:00 P. M.

There were present President Moore and Directors Campbell, Aitken, Black, Benfield and Richardson.

The following new members were elected:

Rev. MIGUEL SELGA, S. J., of the Observatory of Manila, P. I., was elected a Life Member.

ACTIVE MEMBERS

Rev. H. G. BEUHLER of Lakeville, Conn.
Prof. Hamlet Bazzano of the University of Montevideo, Uruguay.
Mr. JOHN B. HASTINGS of Los Angeles, Cal.
Mr. LEWIS A. BINGHAM of Boston, Mass.
Mr. THOMAS W. NASH of Littlehampton, Sussex, England.
Mr. HORACE WILSON of San Francisco, Cal.
Dr. PAUL W. MERRILL of Mount Wilson Solar Observatory, Pasadena, Cal.
Dr. GUSTAF STROMBERG of Mount Wilson Solar Observatory, Pasadena, Cal.
Mr. HAROLD E. MELZAR of Boston, Mass.
Prof. L. C. DAMSGARD of College View, Neb.
Mr. F. W. WOLFE of San Francisco, Cal.

The Secretary reported the receipt of $50.00 from a member of the Society, who does not care to have her name mentioned, as a contribution to the Library Fund. An appropriate letter of thanks was ordered.

Dr. Aitken, for the Committee to arrange for the contemplated course of lectures during the coming winter season, submitted a tentative report, outlining the general plan of the course. This included names of lecturers, subjects, dates, rates of compensation, etc. A resolution was passed by the Board approving of the general plan, and instructing Dr. Aitken to complete his prospectus and submit it to his committee at an early date.

Adjourned.

Officers of the Society.

J. H. Moore	*President*
Bernard Benfield	*First Vice-President*
J. Costa	*Second Vice-President*
A. L. Black	*Third Vice-President*
D. S. Richardson	*Secretary and Treasurer*

Board of Directors—Wm. H. Crocker, C. S. Cushing, D. S. Richardson, J. Costa, R. G. Aitken, G. E. Hale, B. Benfield, W. W. Campbell, A. L. Black, J. H. Moore, Sturla Einarsson.

Publication Committee—R. G. Aitken, H. Shapley, J. H. Moore.
Finance Committee—C. S. Cushing, W. H. Crocker, A. H. Markwart.
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Comet-Medal Committee—W. W. Campbell, Sturla Einarsson, H. M. Jeffers.

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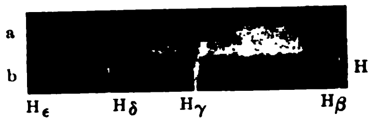

FIG. 2

a. Solar Spectrum
b. Hydrogen

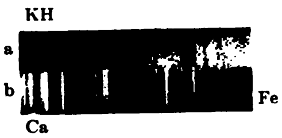

FIG. 3

a. Solar.
b. Fe and Ca.

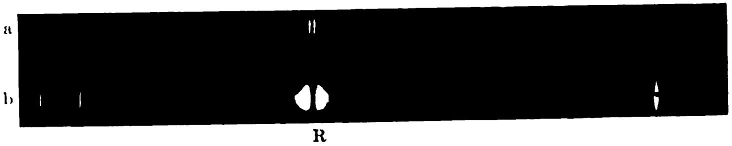

FIG. 4. Arc spectrum of barium

a. Small quantity in arc
b. Large quantity in arc
R. Self-reversal

FIG. 5. Band spectrum, carbon arc

FIG. 6

Nitrogen

a. Band spectrum
b. Line spectrum

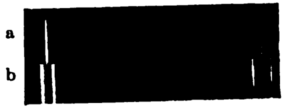

FIG. 7

Zeeman effect, Fe

a. No field
b. With field

PLATE IX

PUBLICATIONS
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THE SPECTROSCOPE, KEY TO CELESTIAL AND ATOMIC MYSTERIES[1]

By E. P. Lewis

About eighty years ago Auguste Comte, in his Positive Philosophy, made the statement that the chemical constitution and the physical state of the heavenly bodies must forever remain unknown to us. Less than twenty years later Kirchhoff and Bunsen established the principles of spectrum analysis and Huggins showed that with the spectroscope we can secure exact information as to the constitution of the stars. From that time to this there has been a steady accumulation of data which throw light not only on the chemical constitution, but also on the physical state and the velocities of heavenly bodies. In this work it is gratifying to know that the two great observatories of California have been leaders, and later in this course of lectures you will learn much of these results from those who have achieved them. Not only has the spectroscope made it possible for us to extend our observations to the remotest parts of the visible universe, but it has also done much to aid us in obtaining some idea of the minute details of atomic structure. The object of this lecture is to explain in the simplest terms the underlying principles of the spectroscope, to show you some experiments illustrating these principles and some photographs of typical spectra, and to give you some idea of the progress which has been made in learning some of the secrets of atomic structure.

The separation of white light into its constituent colors by transparent prismatic bodies must have been observed by the ancients, but Newton was apparently the first to study this phenomenon systematically, and to show that these colors could not be further decomposed by sending them thru another prism, while when recombined they again formed white light. Largely because of Newton's erroneous idea that light consists of small particles projected with great velocities from the source, no further advance was made for more than a century.

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[1] A lecture delivered in San Francisco on Friday evening, October 29, as the introductory one of the course of six popular lectures on phases of the new astronomy to be given this season under the auspices of the Astronomical Society of the Pacific. Laboratory apparatus was utilized to produce on the screen many of the spectra described. Lantern slides illustrations were also used.

Before describing the progress which has been made since the beginning of the nineteenth century, it may be well to describe the simple form of spectroscope which is built up on the table before you. (Fig. 1). A beam of light from an electric arc is focused by a lens on a narrow slit S, which is an essential part of every spectroscope. After passing thru the slit the light goes thru a second lens L, which will form an image of the slit at I on a screen at a certain distance. If the prism P is placed in the pencil of light, the latter will be refracted toward the base of the prism. The different colors will be bent thru different angles, so that the white light is spread out into a long band, called a spectrum, red at one end, violet at the other. If only three colors, definite shades of red, green and violet are present in the light, there will be three slit images in these colors at the points R, G, and V. These are called spectrum lines. This is the basic plan of all spectroscopes, altho they are usually of more complicated mechanical construction. Often the prism is replaced by a diffraction grating consisting of a polished glass or metal plate upon which many thousand close and equidistant lines have been ruled with a diamond point. These produce a number of spectra, due to the separation of different colors by interference between light waves of different lengths. Similar effects may be observed on looking at a distant electric light thru a fine meshed handkerchief. In many cases the eye is replaced by a camera, with which a permanent record of the spectrum may be photographed. In this case the instrument is called a spectrograph.

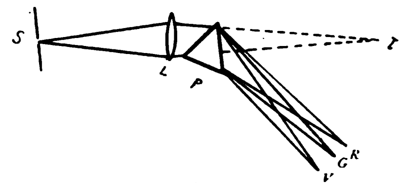

Fig. 1

If we use for a source a flame colored with any compound of sodium the spectrum will consist of two lines very close together in the yellow, each evidently an image of the slit. It is clear that there will be as many slit images, or spectrum lines, as there are colors in the light. The unbroken gradation of colors shown in the spectrum of a candle or of the white hot poles of the electric arc shows that their light consists practically of an infinite number of colors, gradually merging into each other, rather than the seven distinct colors specified by Newton. Such a spectrum is called continuous. You will note that the spectrum of the luminous vapors between the poles of the arc is not continuous, but shows the yellow lines of sodium and several broad bands which are due to carbon or carbon compounds, with dark spaces between them. It is generally true that luminous gases and vapors give such discontinuous spectra, or in other words they emit a finite number of colors.

In the year 1800 William Herschel made the first advance since the time of Newton. He discovered that beyond the red of the solar spectrum there is an intense invisible radiation. This "infra-red" region may be explored with various types of very sensitive thermometers. A little later Ritter discovered similar "ultra-violet" radiations, by the effect produced upon sensitive silver salts. The modern photographic plate is very sensitive to these rays. About the same time Thomas Young showed conclusively that light is due to wave motion. If a pebble is thrown into a smooth pond a circular ripple wave will proceed from it. If two pebbles are thrown in at different points, two sets of waves will be generated. Wherever the crest of one meets a crest of the other the displacement will be increased. Wherever a crest meets a hollow, the waves may neutralize each other completely by destructive interference. You can easily repeat Young's method of producing similar effects with light waves by ruling two fine slits very close together in the gelatine of a blackened photographic plate and looking thru them at the filament of a distant incandescent lamp. You will see a central image of the filament, with a series of narrow spectra on each side. Light of different wave-lengths and color will be reinforced or weakened at different points, so that the different colors are separated from each other. If we multiply the number of such openings, or reflecting grooves in a polished metal plate, we have a diffraction grating, with which measurements of wave-lengths may be easily and accurately made. The longest visible waves give rise to the sensation of red, and have a length of about one thirty-thousandth of an inch. The shortest are the violet, which have a wave-length somewhat more than half as great. Recently it has been shown that X-rays are due to waves of still shorter length, one-thousandth to one ten-thousandth as long as those mentioned above. Their spectra are produced by interference effects due to their reflection from a large number of equidistant atomic planes of crystals.

In 1814 Fraunhofer discovered that the solar spectrum is crossed by a large number of fine dark lines parallel to the slit of the spectroscope, two of which coincided with the bright lines of sodium. It is evident that each dark line indicates the absence of a corresponding slit image, and therefore of that particular color or wave-length in the light of the Sun. These Fraunhofer lines are illustrated by the photographs of the solar spectrum shown in Figs. 2 and 3, Plate IX, and on a much larger scale by the large map of the solar spectrum made by Professor Rowland with a powerful diffraction grating, on which many thousands of these lines appear. The significance of these lines was not apparent at the time. Meanwhile many investigators noted the different colors shown by flames containing salts of sodium, calcium, strontium and other elements, and found that their spectra showed characteristic differences. In 1849 it was noted by Foucault that the yellow lines emitted by a flame colored with sodium correspond exactly in position with two dark lines in the solar spectrum, and he succeeded in reproducing these lines in the continuous spectrum of the electric arc by an experiment which I shall now imitate. The spectrum of the arc is thrown on the screen. Above is the continuous spectrum of the carbon pole. Below it is the spectrum of the flame of the arc, in which the sodium lines are prominent, and are made more intense by the addition of common salt to the arc. Just in front of the slit I burn a piece of metallic sodium in an alcohol flame. As the yellow blaze rises across the slit and thru the beam of light from the arc, you see a broad dark line appear in the continuous spectrum of the latter just above the bright sodium lines. It is evident that the sodium vapor in the flame absorbs more of the yellow light coming from the hotter arc than it emits itself, so that this particular color is greatly weakened in the spectrum of the arc. The great significance of the different discontinuous spectra observed by various individuals, the Fraunhofer lines, and Foucault's experiment was first clearly realized by Kirchhoff and Bunsen in 1859, when they definitely established the conclusion that every luminous gas or vapor emits a limited number of colors, with a corresponding number of slit images, the number and positions of these lines being characteristic of the substance; and further, that in many cases, as in the phenomenon observed by Foucault, such vapors will absorb a large part of the light of the same wave-lengths as they emit if they are placed in the path of the light coming from a brighter source. The differences in the number and positions of the spectrum lines of different elements can be due only to differences in the size and structure of the atoms which are the sources of the light waves, hence it is apparent that there must be a close relation between spectra and atomic structure.

The explanation of the absorption of light causing the Fraunhofer lines was first suggested by Stokes, and was based upon an acoustical analogy. Here are two tuning forks of exactly the same pitch. If one is set into vibration it is found that in a few seconds the other will be vibrating vigorously. This is an example of the familiar phenomenon known as resonance. If I slightly change the period of vibration of one fork by loading it with a bit of soft wax it will no longer respond. The explanation may be made clear by a familiar analogy. The vibrations of a swing may be steadily increased in amplitude by giving it a push in the right direction at regular intervals corresponding to its natural period of vibration. In like manner the initial sound wave starts the second fork to vibrating, and if each succeeding wave arrives at the proper instant to give the fork an additional impulse in the right direction it will soon vibrate with great energy. This will not occur if the periods of the two forks are different, as the effect due to the first waves will soon be neutralized by succeeding waves in different phases. Light waves must be due to the vibrations of parts of atoms, and if all sodium atoms are precisely alike, their periods of vibration must be the same, and we should expect that sodium atoms placed in the path of light waves of the same frequency would have vibrations set up within them, so that some of the incident energy will be absorbed. Some of this is again radiated, but in all directions instead of pursuing the original direction of the incident light, so that there will be a reduction of intensity in that part of the spectrum corresponding to the colors absorbed.

Thus we find a simple explanation of the Fraunhofer lines. Thousands of these lines observed in such a map as that of Professor Rowland coincide exactly in position with the bright lines observed in the spectra of many elements, and we can not doubt that these elements are present in the solar atmosphere. In fact, during a total eclipse the "reversing layer," the relatively cold upper atmosphere of the Sun, emits bright lines corresponding exactly in position with the dark lines due to their absorption of the radiation coming from the hotter part of the Sun below them when the latter is not obscured by the Moon. Fig. 2, Plate IX, shows the spectrum of hydrogen made luminous by an electric discharge directly under the solar spectrum. The strongest hydrogen lines correspond in position with dark lines of the solar spectrum. In Fig. 3, the lower spectrum is that of the spark between iron electrodes moistened with a solution of calcium chloride. Many of the iron lines correspond in position with dark lines and the two intense lines marked *Ca* have the same positions as the two very broad Fraunhofer lines marked *H* and *K*.

When the photographs of a number of typical spectra are thrown on the screen you will observe not only that the spectra of different elements are unlike, but that there are marked differences in the spectra of a given element caused by changes in the physical conditions, such as the density of the vapor, the intensity of the electrical discharge, or the temperature. Some lines are intense and broad in one case, and in another narrow or altogether missing, or new lines may appear. Fig. 4 shows a part of the arc spectrum of barium, the upper with a small quantity in the arc, the lower with a larger quantity. In the second case the lines are stronger, and some new lines appear. The very intense line near the center is very much broadened and in both spectra it shows the phenomenon known as self reversal. The colder vapor around the arc absorbs light of the same wave-length as it would emit, causing a dark line across the center of the bright line. Furthermore, as shown by Fig. 5, which represents a part of the spectrum of the luminous vapors in the arc, not all spectra are composed of widely separated lines. In this case we see a large number of fine lines, arranged with a periodic regularity very close to each other, these orderly arrangements repeating themselves in separate groups. Such spectra are called band spectra. The spectra of all compounds, and also of all elements when the electric discharge is not sufficiently intense to dissociate the molecules into atoms, are composed of bands, hence we may assume that band spectra are due to the molecular state; and the evidence is equally strong that line spectra are due to dissociated and electrically charged atoms. Fig. 6 (a) shows the band spectrum of nitrogen thru which a weak electric discharge passes. The spectrograph was not sufficiently powerful to separate the many fine lines of which these bands are composed. The spectrum (b) below is that of the same gas when a more intense electric discharge passed thru it. The latter is a typical line spectrum.

It is evident from these facts that observations of the spectra of the heavenly bodies may give us much information regarding not only their chemical constitution, but also their physical state, for example their temperature, the density of their atmospheres, and even their magnetic state. If the substance of a star is dense like that of our Sun it will emit a continuous spectrum, and the hot vapors in its atmosphere will cause dark lines by absorption. If it is white hot, all colors will be emitted. If it has cooled down to red heat, its spectrum will be confined to the red. If it is still in a gaseous state, like the nebulae, the spectrum will consist of bright lines.

One of the most remarkable astronomical applications of the spectroscope is to the determination of the velocity of stars in the line of sight with respect to the Earth. The distances of all the stars are so great that it is impossible to determine their angular velocities at right angles to the line of sight except from a series of observations extending over many years. The spectroscope enables us to determine the velocity in the line of sight from a single photograph and down to a fraction of a mile per second. Here again an acoustical analogy will afford an explanation of the method. If this tuning fork is set into vibration its pitch will remain constant as long as the fork is at rest. When it is moved rapidly toward you a rise in pitch is easily observed, and a corresponding lowering of pitch when it is moved away from you. The fork starts a sound wave from its first position. If it moves forward during one vibration it will start the next wave a little in advance of its previous position. In other words, the wave has been shortened so that more waves will reach the ear in one second than if the fork had remained at rest. If the fork moves away from you the waves will be stretched out and fewer of them will reach you. This effect, known as Doppler's principle, applies also to light waves. If a star is approaching the Earth, the wave-length of a given line will be diminished and it will be slightly shifted toward the violet, and toward the red if the star is receding. The spectrum of a terrestrial source containing lines which appear in the spectrum of a star, say the hydrogen lines, is photographed alongside the spectrum of the star. The shift of the lines is then measured, and from this the velocity with respect to the Earth is easily calculated. The distance of the star in no way affects the accuracy of the result. A large part of the work of the Lick Observatory has been the determination of the velocities of a large number of stars in different parts of the sky.

These observations afford data for the determination of the velocity of the solar system itself thru our stellar universe.

What has been said will make it clear how the spectroscope enables us to extend our observations on the constitution, physical state, and velocities of the heavenly bodies thruout the enormous extent of the visible universe. Other lectures in this series will deal more specifically with some of these achievements. Let us now turn our attention to the opposite extreme, to the study of the structure and activities of the infinitesimal atoms of matter which are the ultimate sources of light. Consideration of the origin of musical sounds will help us to interpret spectroscopic observations. Sound waves are emitted from vibrating musical instruments, are transmitted thru the air, and finally set up sympathetic vibrations in the ear which give rise to the sensation of sound. Similarly light waves originate from the vibrations within the atoms or molecules of the source. A tuning fork emits sounds of one definite pitch. This corresponds to an atom which has a spectrum consisting of only one line. As a matter of fact, no element gives such a simple spectrum except under conditions of very feeble excitation. If all the keys of a piano are struck simultaneously, a complex of sounds will be emitted, consisting of a number of fundamental tones and their harmonics. This corresponds more closely to the many-line spectrum of an element, except that in the latter case the vibration frequencies have none of the simple numerical relationships to each other. Apparently an atom must be a much more complicated structure than a piano. We could not from a study of the sounds emitted by a piano arrive at any accurate notion of its mechanical structure, and it may be imagined that the problem must be infinitely more difficult when we have to deal with an atom such as that of iron, having many thousand unrelated lines in its spectrum. Nevertheless, while we can not hope to solve the problem completely, the spectroscope, together with the study of radioactive and other phenomena, has given us a fairly definite general notion of the structure of atoms and of the way in which they emit and absorb light.

In formulating the kinetic theory of gases it was originally assumed, as a matter of convenience, that molecules and atoms are smooth, round, elastic bodies like billiard balls. This assumption will satisfy most of the needs of the kinetic theory, but it is wholly inadequate to explain the radiation of light, for it is impossible for such simple bodies to vibrate in the innumerable ways necessary for the production of a complicated spectrum. About fifty years ago Clerk Maxwell advanced the hypothesis that light waves are electrical in character. The later discovery by Hertz of electric waves which are identical in all respects except length with light waves confirmed this hypothesis. Electrical waves are set up by the vibrations of electric charges between electrodes, so we may infer that light waves are set up by displacements of electric charges in atoms. There was no way in which this process could be pictured until Zeeman made a remarkable discovery in 1896. He found that if a flame colored with sodium is placed between the poles of a powerful magnet each single spectrum line is split into two when the source is viewed in the direction of the magnetic force, and into three when viewed transversely. Fig. 7, copied from a Mount Wilson Observatory publication, shows the separation of two iron lines by the magnetic field. The doublet observed by Zeeman was found to be circularly polarized—that is to say, the electrical disturbance takes place in circular paths, propagated thru space like a vortex. The lines of the triplet were found to be plane polarized, that is to say the vibrations were in one plane, like those of a piano wire. These effects are in complete accord with a theory advanced by H. A. Lorentz, who assumed that radiation is due to the revolution of electrified particles around a central nucleus, as the planets rotate around the Sun. Electrified particles rotating in orbits parallel to the magnetic force will not have their periods of rotation changed. Those rotating in orbits perpendicular to the field will have their periods accelerated or retarded by the magnetic force according to the direction of their motion. This gives rise to two slightly separated lines when the source is looked at parallel to the field. We may imagine (if we accept the existence of an ether) that these revolving particles stir up ether vortices like those set up in a cup of coffee by stirring it with a spoon. This vortex motion propagated with the speed of light, like a rapidly revolving corkscrew in space, constitutes circularly polarized light. If we are looking at the orbits edgewise we see only the transverse components of motion, like the up and down motion of the crank pin of a fly wheel, and thus we get the three plane polarized components due to the particles which are retarded, accelerated, or not affected by the magnetic field. From a study of the direction and magnitude of the displacements of the lines it was determined that these particles are negatively charged, and that they have a mass about one eighteen-hundredth that of a hydrogen atom. They are thus found to be identical with the cathode rays, which J. J. Thomson about the same time showed to have the same charge and mass. These particles are called electrons, and play a great part in modern physics. A study of cathode rays and related phenomena shows that these electrons are constituents of all kinds of matter and under certain conditions may be readily separated from the atoms.

A study of radioactive phenomena leads to similar conclusions, and shows conclusively, moreover, that the heavier atoms, such as those of uranium, thorium, and radium, are constantly breaking down into smaller parts. The old idea of the indestructibility of the atom must therefore be revised, altho these discoveries placed the atomic theory on a firmer foundation than ever. To explain certain anomalies and energy relations the Lorentz theory of the Zeeman effect has been considerably modified, but it still leaves us the picture of the atom as a planetary system. Evidence derived from the study of radioactivity as well as of spectroscopic phenomena makes it seem highly probable that the atoms heavier than hydrogen and helium are built up in the following manner: In the center is a small but relatively heavy nucleus composed of hydrogen and helium atoms and electrons, with an excess positive charge. At distances of the order of one thousand to ten thousand times the diameter of this nucleus a number of electrons revolve in one or more orbits. The diameter of the whole system is about one three-billionth of an inch. The displacements of these negatively charged electrons from an outer to an inner orbit due to some external shock causes the emission of light waves; and light waves of the same frequency may displace an electron from an inner to an outer orbit and thus cause absorption of energy. These external electrons probably also furnish the electrical forces which hold atoms together in chemical combinations. Sometimes, in the case of the radioactive elements, internal equilibrium may be upset in some way unknown to us, resulting in an atomic explosion, so that atoms of helium (alpha particles) may be projected outwards, leaving a smaller atom behind. It has been proved that uranium disintegrates in this manner down to radium, and this in turn down to lead. What happens beyond that we do not know, but we can infer the probability of other atomic disintegrations. In fact, Rutherford has recently almost conclusively proved the possibility of breaking down nitrogen atoms into helium and hydrogen atoms by the impact of swift alpha particles.

Such is the picture of the atom revealed to us by the study of spectroscopic and radioactive phenomena. Time does not permit a detailed examination of the evidence, and many points are still unexplained; but physicists have abundant reasons for believing that the real atom can not greatly differ from the hypothetical atom described above.

We thus see that each atom is a miniature solar system. The question naturally arises—but can not now be answered—Does nature repeat itself *ad infinitum;* are there other systems smaller than those of atoms?

RECORDS OF NIGHT CLOUDINESS FOR ASTRONOMERS

By Alexander McAdie

When in those golden days of yore in the land of hope and progress we walked and talked[1] of things great and small, the Nestor of science on the Pacific Coast, the head of the Lick Observatory, remarked:

"This would be a good world for the astronomer, if there was no atmosphere!"

Now we humble aerographers have been trying to find out something concerning this very shallow shell of air that surrounds the planet; but as yet we have done very little to help the astronomer; and the thought will come that perhaps progress would be greater if astronomers themselves would lend a hand. This paper is a plea for such effort.

The atmosphere is only about 100 kilometers in depth and for practical purposes we need consider only the lowermost tenth of that. At the 10 kilometer level we are above the clouds. Some few cumulo-nimbi poke their heads higher on summer afternoons, but these do not interfere with the work of the astronomer.

In the following table the mean cloud heights as determined at Blue Hill in various ways (theodolite, sounding balloon, pilot balloon and kites) are given.

CLOUD HEIGHTS

NAME	MEAN HEIGHT IN METERS		DEFINITION
	Summer	Winter	
Cirrus............	9900	8050	Thin, fibrous, detached, feather-like clouds.
Cirro-stratus......	8750	7850	Thin, white veil, more or less fibrous.
Cirro-cumulus.....	7606	6992	Small, white cottony balls in flocks,
Alto-cumulus.....	3195	2931	Large, more or less rounded balls. flat disks, or rolls or fleecy flocks.
Alto-stratus.......	6481	2930	A gray or blue veil exhibiting in the vicinity of the Sun or Moon.
Strato-cumulus....	1957	1830	Large gray balls; or rolls in close contact[2].
Cumulus.........	1473	1381	Thick clouds whose summits are dome-like with protuberances; bases flat.
Fracto-cumulus....	1235	1220	Flat, broken clouds of the cumulus type.
Cumulo-nimbus...	1202	1552	Massive clouds from which showers fall.
Nimbus..........	712	....	A dense, dark sheet of ragged cloud from which rain or snow usually falls.
Stratus...........	583	503	Lifted fog in horizontal stratum.

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[1] See Presidential Address, *Publ. Astron. Soc. Pac.*, **26**, No. 153, Jan., 1914.

[2] See *Principles of Aerography*, p. 117; also Clayton's "Discussion of Cloud Observations," Harvard Observatory *Annals*.

But there is now a more direct way of determining cloud heights and velocities, namely, by airplane, which enables us to get to the cloud and not only measure the bottom of the cloud but the top as well.

Aviators can climb quickly to the very top of cloudland, that is, to the bottom of the stratosphere, the beginning of the major temperature inversion. And let it be noted that inversions must be reckoned with in all questions of atmospheric refraction. Perhaps if we knew a little more about inversions at times of total solar eclipses, we could account for a portion of the shift of star images. Be that as it may, during the next eclipse, provision should be made for observations of air temperature and density at different levels, by means of airplanes.

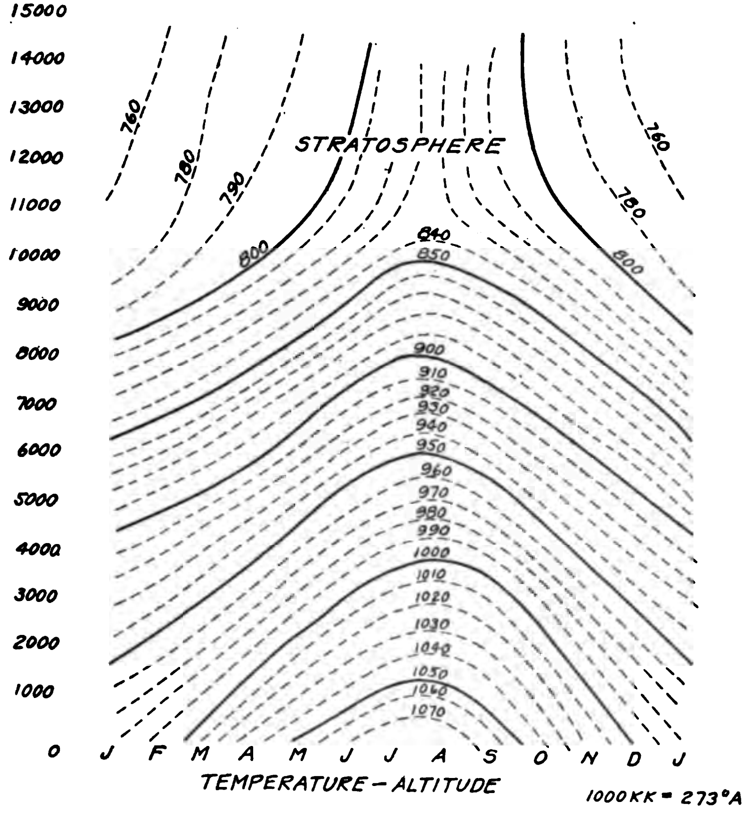

FIG. 1

Computing the heights reached by two American airmen (record heights) and correcting the altimeter readings for temperature, humidity, gravity variation with altitude and latitude, I make the elevation of Major Schroeder of the Air Service, February 27th, 1920, at McCook Field, to be 9915 meters (32527 feet). This differs slightly from the Bureau of Standards' round number; but the data used are those kindly supplied by the Bureau. I make Roland Rohlfs' best height (September 18, 1919, at Mineola) 9645 meters (31646 feet).

We have here a winter and a summer flight.

As we all know, an adiabatic temperature gradient, called abroad "the lapse rate" is 30.26 kilograds (9.87°A) per kilometer. But such a rate seldom prevails, and we find in moderately saturated mixture of air and vapor in stable condition, an average lapse of 22 kilograds (6°A). A good idea of the temperature at levels up to the stratosphere for a year can be had by inspection of Fig. 1 (Temperature—Altitude) in which temperature is expressed on the Kelvin Kilograd scale. The isotherm of 1000 for example, is the freezing point (32°F) and one sees that even in midsummer such a temperature is found at 4000 meters.

Similar charts are available for pressure and density. But for the special purpose of the astronomer, namely, the forecasting of night cloudiness, we need, particularly, charts showing the distribution of water vapor, its pressure in kilobars and its weight in kilograms per unit volume of space, that is, its density.

Some idea of the annual distribution of water vapor in units of force is given by Fig. 2.

Cloudiness is simply the process of making visible the previously invisible water vapor. Cooling is the effective agency and this cooling may be brought about by lifting, by radiation, by mixing or by conduction. In lifting a given volume of air and vapor, there is expansion due to decreased pressure, and hence cooling. The astronomer, therefore, must regard all anabatic (up-rising) winds as potential cloud builders. The second operative cause of cooling namely, radiation, is all important. For a maximum effect, still air and dust-free air are needed. Much of the cloudiness of low levels, the valley fogs, and the early morning stratus of coastal sections, are caused by radiation cooling during the night hours and consequent saturation temperatures. The third cause, mixing, is more apt to be associated with higher level clouds and the movement of air either horizontally or vertically. We know comparatively little about the vertical winds; but horizontal winds we partially measure. Fig. 3 shows average values at different levels, also the "structure" of the air under different conditions such as the sea-breeze or the approach of a cyclone from the south, "sea-turn."

It is evident that high velocities are found just under the stratosphere.

Some mean velocities determined from cloud drift are:

10000	meters	45.6 m/s	(102 m/h)
10400	meters	40.2 m/s	(89.9 m/h)
10800	meters	40.0 m/s	(89.5 m/h)
11200	meters	37.8 m/s	(84.6 m/h)

Among the Blue Hill Cloud records is one made February 21, 1897, in the afternoon, showing a cirro-stratus, elevation 9946 m., moving from 270 (W) with an apparent velocity of 84 m/s (188 m/h). Again on the morning of February 25th, cirrus, elevation

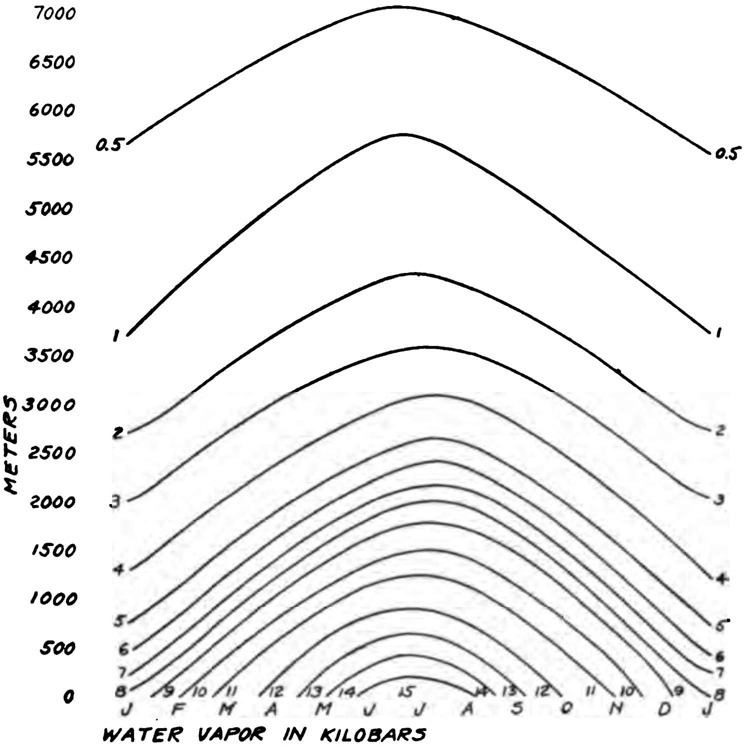

Fig. 2

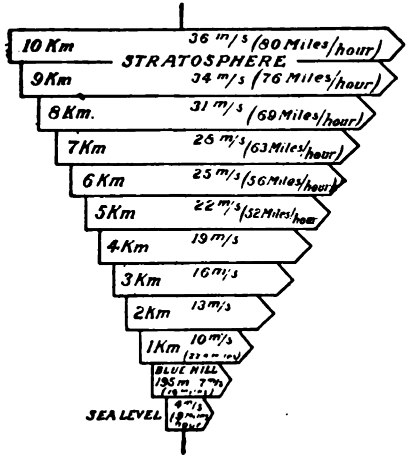
10 Km 36 m/s (80 Miles/hour)
STRATOSPHERE
9 Km 34 m/s (76 Miles/hour)
8 Km. 31 m/s (69 Miles/hour)
7 Km 28 m/s (63 Miles/hour)
6 Km 25 m/s (56 Miles/hour)
5 Km 22 m/s (52 Miles/hour)
4 Km 19 m/s
3 Km 16 m/s
2 Km 13 m/s
1 Km 10 m/s
BLUE HILL 195 m 7 m/s
SEA LEVEL 4 m/s

FIG. 3 (a)

Increase of Velocity with Elevation

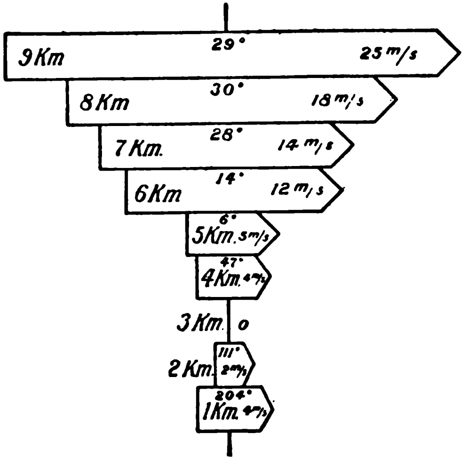

FIG. 3 (b)

Sea-Breeze Structure

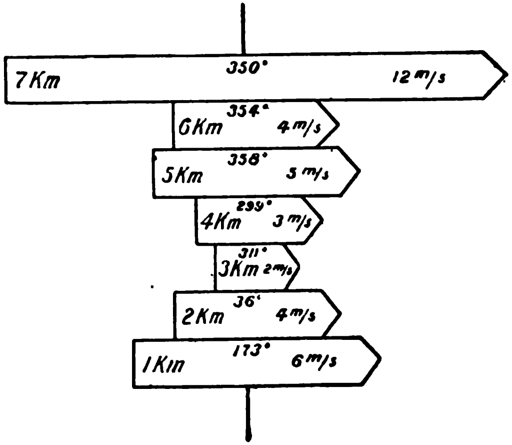

FIG. 3 (c)

Sea-Turn Structure

9610 m., moves from 225 (WSW) with a speed of 94 m/s (210 m/h). Finally the banner record for air speed, a cirrus on October 12th, 1891, moving 102.6 m/s or 228 miles per hour.

It is something of a problem to know in advance the probable level of cloudy condensation, for there are many independent variables. Still we must try to solve it. We are learning that air falls as well as rises. It is the falling which frequently dissipates the cloudiness, for here is dynamic heating. Falling air, however, often fails to reach the ground, being fanned out in the lower levels. So we get inversions and sheets of cloud with much warmer clear weather just above the sheet, generally wide spread.

If we except the familiar sea fog brought in by the low level winds, the fog or cloud that bothers astronomers most is this low level inversion cloud. Happily the astronomers on the Pacific Coast can get above many of the cloud sheets; but their brethren elsewhere suffer.

Now why should not all astronomical observatories maintain autographic cloudiness recorders? This suggestion may shock astronomers, for surely they of all people—these pilgrims of the night—know and note in their records the conditions favorable or unfavorable for work. Perhaps so; but how many observatories have in operation so simple a device as a Pole-Star Recorder? This ininstrument, devised by an astronomer, the late Professor E. C. Pickering, in 1885, has been in operation at Blue Hill since 1888, having been used before this at Harvard College Observatory. The writer may be mistaken and hopes he is; but so far as known, for over thirty years the only record of night cloudiness has been the one at Blue Hill. In official weather reports such a thing as a night cloudiness record does not exist. This is true abroad as well as at home. Some tale of the night must be kept, but chiefly this is based on the Night Watchman's or the Early Milkman's say so.

The principle of the instrument is simple and the original cost and expense of maintaining, quite small. *Polaris* and *δ Ursae Minoris* thru a long focus lens give on a small photographic plate star trails; full, if the night is clear, broken, if the night is intermittently cloudy, and no trail if entirely cloudy. For details of the instrument see references[3].

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[3] *Principles of Aerography*, McAdie, page 133, for this and also a Moonlight intensity recorder
B. C. Kadel, in *Monthly Weather Review*, Vol. 47, page 154, March 1919.
S. P. Fergusson, *Quart. Journ. Roy. Meteor. Soc.*, Vol. XXXI, page 309, October, 1905.

And now comes the Royal Observatory at Greenwich in this year of grace 1920, and installs a Pole-Star Recorder; and the meteorologists of the United Kingdom return thanks. One should read the discussion in the *Quart. Journ. Roy. Meteor. Soc.* for July, 1920, p. 243, to taste the humor of the situation, for it had evidently been forgotten by all that Fergusson, fifteen years ago, had published in that very journal a full account of the instrument.

The Astronomer Royal will, we hope, proceed now to add to the equipment of the Observatory an airplane.

The University Observatory at Chicago has also recently installed a Pole-Star Recorder. How many observatories on the Coast are giving attention to these problems of night cloudiness? For a knowledge of air structure, night cloudiness is better than day cloudiness, for we are free from the disturbing effect of solarization. The Sun, so generally regarded as a cloud dispeller, can also, as the late Dr. John Aitken showed, act at times as a cloud builder. As Sir Napier Shaw points out records of night cloudiness are preferable to sunshine records in studying the dynamics of the atmosphere.

May we then venture to suggest that astronomers wait no longer for aerographers to solve the problems of night cloudiness; but make a start, even if only by the installation of so simple a device as a Pole-Star Recorder? In time other instruments must come, simple too, but telling of any interception by means of cloud of the radiant heat from the Earth. Astronomy is in its essence a reaching out from Earth into space; why then shall we not reach out and record the temperature, pressure, density, vapor content, heat gain and heat loss, in the different levels of our own atmosphere, especially so since these bear directly upon the efficiency of every observatory?

THE PROBABLE DIAMETERS OF THE STARS

By Henry Norris Russell

1. It would be very easy to determine the angular diameters of the stars if only we knew their surface brightness. If d is the apparent diameter of any star, m its visual magnitude, and J its surface brightness, it follows from elementary considerations that

$$d=C\ 10^{-0.2m}\ J^{-\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

On inserting the data for the Sun ($d=1920''$, $m=-26.72$) the constant C is found to be $0''.0087$, provided that the Sun's surface brightness is taken as unity. If $j=-2.5 \log J$[1] (so that it represents the change in stellar magnitude corresponding to a change in surface brightness in the ratio J:1), (1) may then be written

$$d=0''.0087\ (0.631)^{m-j} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

No direct way of finding j is at present available; but several indirect ways are open. In comparing their results, and applying them to the stars in general, (which the present paper attempts to do in a provisional and tentative fashion), the following proposition is fundamental.

The difference of surface brightness of two stars (when expressed in stellar magnitudes) is proportional to the difference of their color indices. If i denotes the color-index we have then, for any two stars

$$j_2-j_1=k\ (i_2-i_1) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The constant k depends on the wave-lengths of the light used in measuring the surface brightness and color index, but is the same for all stars.

2. For an ideal radiator, equation (3) will be very nearly true. If the effective wave-length is λ for visual magnitudes, and λ^1 for photographic, the relation

$$k=\frac{\lambda^1}{\lambda-\lambda^1} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

will be substantially exact, so long as Wien's formula may safely be employed. At higher temperatures, when Planck's formula must be used, the value of k gradually increases, since, for an infinite temperature, this formula gives an infinite surface brightness, but a finite color index.

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[1] In this discussion, all logarithms are supposed to be to the base 10.

The only celestial body which permits of a direct observational test of (3) is the Sun. The work of Schwarzschild and Abbot makes it probable that different parts of the Sun's disk differ in color and brightness because at the center we see down deeper, and into hotter layers, than near the limb, where our line of sight is oblique. This theory has recently been strongly confirmed by Lindblad[2] who has shown that it accounts quantitatively for the distribution of energy over the disk in the different wave-lengths.

It is therefore reasonable to suppose that, on passing from the center to the limb of the Sun, we meet successively with radiative conditions very similar to those met with in the photospheres of cooler stars. The principal difference between the two cases is that the outermost layers are at the same temperature for all points of the Sun's disk, but are cooler in the cooler stars; but as these upper layers contribute very little to the general emission, the effect of this difference on the color index will presumably be small—tho it will be otherwise in the case of the line-absorption, which is mainly produced in the upper layers.

The range in brightness and color is relatively small, but this is compensated by the great accuracy of the observations. The results derived from Abbot's observations[3] of 1913 are given in Table I. The upper part of the table gives the differences of surface brightness, expressed in stellar magnitudes, between the center of the disk and regions at various distances from it, for seven wave-lengths. Color indices, relative to the center of the disk, are then formed by subtracting the brightness for 0.5955μ from the others, and the lower part of the table gives the ratio of the color index for each of the other wave-lengths to the surface brightness for the standard wave-length. These ratios are very nearly the same for all points on the disk, so that equation (3) is confirmed. For brevity the data for some of the intermediate points have been omitted. These also agree with (3).

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[2] *Upsala Universitets Arsskrift*, 1920, **1**, 1340.

[3] *Smithsonian Misc. Collections*, **66**, No. 5, p. 7, 1916.

TABLE I

Surface Brightness j of the Sun's Disk, Referred to the Center

DISTANCE FROM CENTER	WAVE-LENGTH						
	0.3737µ	0.4265	0.5062	0.5955	0.6702	0.8580	1.0080
0.40	0.074	0.071	0.054	0.046	0.037	0.031	0.028
0.65	0.227	0.226	0.174	0.144	0.123	0.095	0.087
0.825	0.465	0.460	0.357	0.292	0.250	0.195	0.176
0.92	0.754	0.729	0.571	0.466	0.400	0.308	0.280
0.95	0.912	0.879	0.692	0.565	0.485	0.372	0.337

Ratio i/j

0.40	0.58	0.52	0.17	.....	−0.19	−0.31	−0.40
0.65	0.58	0.57	0.21	.....	−0.15	−0.34	−0.40
0.825	0.59	0.58	0.22	.....	−0.14	−0.33	−0.40
0.92	0.62	0.56	0.22	.....	−0.14	−0.34	−0.40
0.95	0.61	0.57	0.23	.....	−0.14	−0.34	−0.40
Means...	0.596	0.560	0.210	.....	−0.152	−0.332	−0.400
Equation (4)....	0.594	0.396	0.194	.....	−0.111	−0.306	−0.409

The mean observed values of $\frac{1}{k}$ are given at the bottom of the table. In some cases they agree closely with those predicted by equation (4) taking $\lambda = 0.5955$; but in others the discordance is considerable, indicating a departure from black body conditions.

3. It is still somewhat uncertain how far it is safe to go in assuming that similar relations between surface-brightness and color index hold good among the stars generally. There is conclusive evidence, mainly derived from variable stars, that redness and low surface brightness *generally* go together. On the other hand, Campbell[4] points out that the companion of *Sirius*, tho of spectrum A, probably has a very much smaller surface brightness than the principal star. The same argument applies, with even greater force, to the faint double companion of o² *Eridani*. It must remain for the future to determine whether the surface brightness of these stars is actually low, in spite of their A-type spectra, whether (as Hertz-

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[4] *Pub. Astron. Soc. Pacific*, **32**, 199, 1920.

sprung[5] has suggested in another case) their light comes mainly from small areas upon their surfaces, or whether still another solution of the riddle is the true one.

Plaskett[6] has also called attention to certain eclipsing binaries in which a large difference in surface brightness is accompanied by very little difference in spectral type. In the most striking of these, RS *Vulpeculae*, the spectrum of the component of low surface brightness is barely perceptible in the violet, tho the visual brightness of the components is almost equal. This suggests strongly that there is a considerable difference in color index, in the usual direction and reduces the case to one in which the color indices of stars of nearly similar spectral type are different.

Such differences are frequent among the redder stars, and are apparently closely associated with the absolute magnitude[7]. In extreme cases they may be as great as half a magnitude, but their average value must be much smaller.

It may be concluded, provisionally, that the surface brightness of a star may be estimated, from its spectral type, with an uncertainty which is usually much less than the average difference in surface brightness between consecutive spectral types, tho it may occasionally reach this limit, and, for a very few exceptional stars, may be more seriously in error.

4. We may now proceed to discuss the various means at present available for determining the constant k, which expresses the ratio of surface brightness to color index. In order to have this really constant we must define our system of color indices. Determinations by different observers and methods differ—some being on a much more open scale than others—but all become nearly consistent when the color indices of each series are divided by that found for stars of Class K, which is called the color equation of the given system[8]. A system for which the color index of Class K is exactly 1.00 was suggested by Pickering as a standard. Let K be the value of k, referred to such a system. For any other system of color indices, with a color equation E we have

$$k=K/E$$

This new constant K is the difference of surface brightness in visual magnitudes between stars of Class A and Class K.

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[5] *Astrophysical Journal*, **42**, 117, 1915.

[6] *Publ. Astron. Soc. Pacific*, **32**, 230, 1920.

[7] Seares. *Proc. Nat. Acad. Sci.*. **5**. 232. 1910

[8] See for example Schwarzschild, *Göttingen Aktinometrie;* also *H. A.*, **76**, No. 4, (1914), **80** No. 9, 1917.

5. The various investigations based on "black body" assumptions, can be utilized to determine K, if the wave-lengths which correspond to the various systems of magnitudes are known. Much less evidence is available on this important matter than there should be; but, fortunately, Parkhurst[9] in the Yerkes Actinometry, has given data which (amplified by information which he very kindly furnished by letter) makes it possible to determine[10] that the mean effective wave-length (Crova wave-length) for his photo-visual magnitudes is approximately 0.541μ and that for his photographic magnitudes is 0.428μ.

From these wave-lengths it follows from (4) that $k=3.8$ for Parkhurst's color indices. These require correction for the systematic difference between his estimates of spectral type and those made at Harvard[11] but for Class K this correction is almost negligible, and we may take $E=1.27$. Hence we find from Parkhurst's data $K=4.8$. By comparison of the Harvard systems of magnitude with Parkhurst's, it appears that the effective wave-length for the visual observations is 0.516μ and for the photographic 0.419μ.

An independent system of color indices has been derived by Rosenberg[12] from photographic spectra and gives the intensity at 0.400μ relative to that at 0.500μ. Arranging his data according to the Harvard classification of spectra, we find a mean color index of $+0.10$ for 14 stars of Class A and of $+1.83$ for 12 stars of Class K. From this, we have $K=6.7$ for visual light of wave-length 0.52μ.

We may also utilize the stellar temperatures determined spectrophotometrically by Wilsing and Scheiner[13]. These give a mean temperature of 10600° for 17 stars of Class A, and of 4400° for 28 stars of Class K, whence by Planck's formula, for $\lambda=0.52\mu$, $K=4.0$.

6. The value of K may also be determined from other astrophysical data, without the need of assuming black body conditions. The most direct evidence is afforded by the eclipsing variable U *Cephei*, in which the brighter component is of Class A and the fainter star, which eclipses it totally, of Class K[14]. The ratio of surface brightness of the two stars according to Shapley[15] is 20, according to the solution in which the star-disks are assumed to be of uniform brightness, and 17, if the disks are assumed to be dark-

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[9] Ap. J. **36**, 169, 1912.

[10] Russell, *Pub. Amer. Astron. Soc.*, **2**, 162, 1915.

[11] *Ap. J.*, **36**, 188, 1912.

[12] *A. N.*, **193**, 357, 1913.

[13] *Potsdam Publ.*, **19**, 63-65, 1909.

[14] Miss Cannon, *Pop. Astron.*, **25**, 314, 1917.

[15] *Princeton Contributions*, **3**, 83, 1915.

ened at the limb. The mean of the corresponding differences of magnitude gives $K = 3.2$.

A similar, but independent method depends on the determination of the differences of color index and surface brightness among totally eclipsing variables. The results for seven such systems[16] give the mean value $k = 0.18$, but there is considerable uncertainty regarding the color equation of both the visual and photographic magnitudes for stars as faint as these are at minimum (from 9.2 to 12.1 on the Harvard visual scale). From the data given by Pickering[17], it appears that, when magnitudes derived from ordinary star images on the Harvard photographs are compared with the Harvard visual magnitudes, the color equation, E, between Classes A and K is +0.92 for stars brighter than 8.5 (visual); +0.75 for stars between 8.5 and 9.5, and +0.55 between 9.5 and 10.5. For stars fainter than 10.5 the very small value +0.19 was found; but this is probably affected by the well-known statistical error arising from the fact that this limiting group consists largely of stars for which the visual magnitudes have been estimated too faint. If we neglect this, and assume that the value for stars of the 10th magnitude is applicable to our stars, which at minimum average 11.2, we have $K = 0.55/0.18 = 3.1$; but this value is unfortunately very uncertain. Re-observation of these and similar stars, by methods of accurately determined color equation, would yield a very valuable determination of this constant.

Still another method involving eclipsing binaries, but independent of the others, is the comparison of the densities of the stars of the various spectral classes, derived from such systems, with the relation between density and surface brightness, derived from visual double stars. The results of the writer's investigation[18] may be summarized as follows:

SPECTRUM	B	A	F	G	M
j	−1.2	−0.0	+0.9	+2.0	>+4.5
i	−0.3	0.0	+0.3	+0.7	+1.6

It may be concluded that the surface brightness j is 3.1 times the color index i on the Harvard scale. As the latter is +1.12 for Class K this gives $K = 3.5$.

Finally, the concomitant variations in magnitude and color index among Cepheid variables may be interpreted as giving the constant

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[16] Russell, Fowler and Borton, *Ap. J.*, **45**, 344, 1917.
[17] *H. A.*, **80**, 148, 1917.
[18] *Pop. Astron.*, **22**, 339, 1914.

k, provided that it is assumed that the observed variation is due to changes of temperature in a radiating surface of constant area. The last part of this assumption is very dubious but, taking it for what it is worth, we find (utilizing a table given by Seares and Shapley[19]) that for 10 stars the mean range in visual magnitude is 0.75 and in color index 0.40; this gives $k=1.87$, and, if $E=1.2$ (as assumed by the observers), $K=2.3$.

7. Collecting the results of these estimates, we have

Parkhurst, color indices	$K=4.8$
Rosenberg, color indices	6.7
Wilsing and Scheiner, temperatures	4.0
U *Cephei*, direct observations	3.2
Eclipsing variables, color index	3.1
Comparison of Ecl. Var. and binary stars	3.5
Color change of Cepheids	2.3
General mean	3.9±0.4

These results are doubtless of very different accuracy; and, excepting the single instance of U *Cephei*, all of them are subject to sources of uncertainty, observational or theoretical. On the whole, they agree surprisingly well. The probable error of the mean has been computed from the residuals according to the usual rule, but should not be taken too seriously. It appears, however, that if the round number $K=4.0$ is adopted, the error is not likely to exceed one magnitude.

8. It remains to estimate the surface brightness for other spectral classes. With the value of K just adopted this will be four times the color index on the standard scale (with color equation 1.0). This scale has been discussed by Pickering[20], who finds that the results of various observers using different methods are on the whole remarkably consistent. His final table suffers, however, from the disadvantage that the color indices for intermediate spectral classes (such as F5) have been determined by interpolation between the nearest even classes. There is no more theoretical justification for assuming that the color index of Class F5 is half way between those of F0 and G0 than for assuming that G is half way between F and K. It seemed therefore desirable to repeat the computation, keeping the stars of each spectral subdivision separate. This made it necessary to exclude the magnitudes of the Draper Catalogue and the C. P. D. from the discussion, since the data given for them in *H. A.* **64** are insufficiently itemized. The

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[19] *Ap. J.*, **48**, 238, 1918.
[20] *H. A.*, **80**, 147-152, 1917.

results for the other four observers are summarized in Table II[21], which gives for each observer the color index, reduced to the standard scale by division by the color equation given at the bottom of the table. Parkhurst's data have been corrected for the systematic deviation of his spectral estimates from the Harvard scale, and Schwarzschild's values depending upon the more accurate spectral classification of *H. A.* **56** have been adopted. The concluded mean scale of color indices is given in the sixth column. The average deviation from the values given by Pickering is only $\pm 0^{m}.03$ for spectra from B2 to G5 inclusive; but for spectra later than *K* the differences are large and systematic, averaging $+0^{m}.19$. The main reason for this is that the group called "M" by Pickering is composed of Classes K5 and M in nearly equal numbers, and should have been called K7 or K8. Neglect of this makes Pickering's adopted color indices for these stars too small. There is additional evidence, however, that K2 and K5 are really nearer to M than their designations indicate. The color-indices are expressed in hundredths of a magnitude.

TABLE II

SPECTRUM	KING	SCHWARZ-SCHILD	PARKHURST	*H. A.* **80**	MEAN
B 2	− 25	− 14	.....	− 22	− 21
B 5	− 15	− 8	− 28	− 1	− 13
B 8	− 11	− 8	− 13	− 7	− 10
A 0	0	0	0	0	0
A 2	+ 11	+ 6	+ 9	+ 14	+ 10
A 5	+ 18	+ 23	+ 17	+ 22	+ 20
F 0	+ 30	+ 33	+ 26	+ 24	+ 28
F 5	+ 40	+ 30	+ 39	+ 39	+ 37
F 8	+ 50	.....	+ 51	+ 49	+ 50
G 0	+ 63	+ 49	+ 55	+ 43	+ 53
G 5	+ 87	+ 69	+ 75	+ 71	+ 76
K 0	+100	+100	+100	+100	+100
K 2	+134	+139	+110	+116	+125
K 5	+144	+147	+121	+134	+136
M a	+147	+152	+136	+163	+145
M b	+168			+160	+154
N	.....	.....	+210	.....	+210
Color Equation	+112	101	127	89	.....

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[21] Data for Class N are added from Parkhurst, *Ap. J.*, **35**, 132, 1912.

9. We are now in a position to estimate the apparent angular diameter of any star, using equation (2). The calculation may be most conveniently made by means of the two small tables given below. Table III gives the quantity $-j$ (which is -4 times the color index, on the standard scale, referred to Class G0 as standard.) The quantity taken from this table, with the spectral class as argument, is to be added algebraically to the visual magnitude of the star. Entering Table IV with this sum as argument, the diameter d of the star in thousandths of a second of arc is immediately obtained, if m-j lies between 0 and 5. For other values of this quantity it is to be remembered that a change of five magnitudes corresponds to a change in diameter by a factor of 10.

TABLE III

SPECTRUM	$-j$
B 0	$+3^m.2$
B 2	$+3.0$
B 5	$+2.7$
B 8	$+2.5$
A 0	$+2.1$
A 2	$+1.7$
A 5	$+1.3$
F 0	$+1.0$
F 5	$+0.6$
F 8	$+0.1$
G 0	0.0
G 5	-0.9
K 0	-1.9
K 2	-2.9
K 5	-3.3
M a	-3.7
M b	-4.0
N	-6.3

TABLE IV

$m-j$	d	D
$0^m.0$	$8''.7$	9.2
0.5	6.9	7.3
1.0	5.5	5.8
1.5	4.3	4.6
2.0	3.4	3.7
2.5	2.7	2.9
3.0	2.2	2.3
3.5	1.7	1.8
4.0	1.4	1.5
4.5	1.1	1.2
5.0	0.9	0.9

10. When the parallax is known, the linear diameter of the star may also be determined. If M is the absolute magnitude of the star (the Sun's absolute magnitude being $+4.83$), and K its actual diameter, taking the Sun's diameter as unit, we find at once

$$D=9.22\ (0.631)^{M\text{-}j}$$

The values of this quantity may be taken directly from the last column of Table IV, with M-j as argument. As numerical examples we may take: (1) *Sirius*. Spectrum A, $m=-1.6$, $M=+1.3$. Hence $-j=+2.1$, $d=0''.0068$, and $D=1.9$ times the Sun's diameter. (2) *α Scorpii*. Spectrum Map, $m=+1.2$, $M=-4.0$ (with the parallax $0''.0089$ resulting from its obvious connection with Kapteyn's *Scorpius-Centaurus* group). In this case $j=-3.7$,

$d=0''.027$, and $D=300$ times the Sun's diameter. The actual diameter comes out remarkably large, almost equal to that of the orbit of *Mars*[22].

11. In seeking stars which have probably a large angular diameter, redness is even a more important guide than apparent brightness. If, for example, we want stars of diameter exceeding $0''.01$ we must have $m\text{-}j<-0.3$. No star of the solar type or "earlier" passes this test,—even *Sirius*, *Canopus* and *α Centauri* fail. But the limiting magnitude for Class K is $+1.6$, for K5, $+3.0$, and for Class M, $+3.4$, while for Class N it is $+6.0$,—including a number of stars in each case. A list of the stars admitted by this criterion is given in Table V.

The most remarkable case of all is the very red star VX *Andromedae* ($+43°$ 53) which has a color index of $+4.56$, according to Parkhurst. The corresponding value of $-j$ would be -12.3. The visual magnitude is irregularly variable thru a small range, but averages about 8.2. This makes the computed angular diameter $0''.054$, which is greater than that of any other star in the sky. It would be straining our assumptions beyond reasonable limits to take this calculation very seriously; but it is clear none the less that the very red stars of which this is an example [23] are objects of much interest.

TABLE V

Star	Mag.	Sp	d
α Orionis	0.9	Ma	$0''.031$
α Scorpii	1.2	Map	.028
γ Crucis	1.6	Mb	.026
α Tauri	1.1	K5	.024
β Gruis	2.2	Mb	.020
α Bootis	0.2	Ko	.019
$α_2$ Centauri	1.7	K5	.018
β Pegasi	2.6	Mb	.016
β Androm.	2.4	Ma	.015
α Triang. Aust.	1.8	K2	.015
19 Piscium	5.3	N	.014
α Ceti	2.8	Ma	.013
η Sagittarii	3.2	Mb	.013
B Can. Venat	5.5	N	.013
β Geminorum	1.2	Ko	.012
α Arietis	2.2	K2	.012
α Hydrae	2.2	K2	.012
π Puppis	2.7	K5	.012
δ Ophiuchi	3.0	Ma	.012
σ Librae	3.4	Mb	.012

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[22] Compare the calculations of Hnatek, *A. N.* **198**, 35, 1914.

[23] See Miss Cannon, *H. A.* **91**, 11, 1918.

U Antliae	5.7	N	.012
− 57°.513	5.7	N	.012
γ Draconis	2.4	K5	.011
γ Hydri	3.2	Ma	.011
μ Geminorum	3.2	Ma	.011
α Herculis	3.3	Mb	.011
D. M.−42°.2818	6.0	N	.010
α_1 Centauri	0.3	Go	0.008
α Can. Min	0.5	F5	0.005
α Carinae	−0.9	Fo	0.009
α Aquilae	0.9	A5	0.003
α Can. Maj	−1.6	Ao	0.007
α Lyrae	0.1	Ao	0.003
β Orionis	0.3	B8	0.0023
β Centauri	0.9	B1	0.0014
ε Orionis	1.7	Bo	0.0009

A few of the brightest stars of "earlier" spectral classes have been added at the end of the table to illustrate the contrast in diameter between these and the redder stars.

In the present state of our knowledge, the star-diameters given above should be regarded only as rough estimates; but in most cases they probably indicate the order of magnitude of the actual diameters. The error is likely to be greatest for those stars which differ most from the solar type of spectrum; and this would be especially true of the faint red dwarf stars, among which, as Hertzsprung has shown, the effective wave-length remains nearly the same over a considerable range of absolute magnitude.

Taking the brighter component of Krüger 60 as an example, we have spectrum, Mb.; abs. mag., +11.7; and mass, 0.3 times the Sun's. The tables give $D=0.27$, and a density 15 times that of the Sun. A decrease in the estimated surface brightness by one magnitude would give $D=0.42$, density = 4, which appears more probable.

It is probably safe to conclude that a few of the brightest and reddest stars have apparent diameters of 0″.02, or a little more, and that they are very attractive objects for investigation with the new Michelson interferometer, which has had such remarkable success in resolving *Capella* as a double star.

Princeton University Observatory
1920, October 7.

A SPECIAL FIELD OF USEFULNESS FOR SMALL TELESCOPES IN PHOTOGRAPHING STELLAR SPECTRA

By Paul W. Merrill

The idea that it is hopeless or unwise to attempt any problem of investigational astronomy with a small or moderate-sized telescope is certainly ill founded. Large instruments have not and will not destroy extensive fields of usefulness for small instruments. The professional or amateur astronomer with a telescope having an aperture of four inches or more, has plenty of attractive opportunities for useful investigation, in addition to the joys of general observation. For example, he may do photometric work on variable stars, or photograph stellar spectra with an objective prism, or make interesting and valuable experiments bearing on new applications of the Michelson interference methods.

In stellar spectroscopy there is a special field of usefulness for small telescopes which has never been fully exploited and which it is the purpose of this article to describe.

The spectra of stars can be efficiently photographed with small telescopes by placing a prism (say of 15° angle) over the object glass. The image of each star in the focal plane will then be a spectrum instead of a point. The spectrum can be kept narrow, or can be widened by placing the edge of the prism parallel to the celestial equator and allowing the exposure to proceed while the telescope is moved by its driving clock at a rate slightly different from that at which the telescope exactly "follows" the star. It would take too much space even to mention the results already achieved by the application of this method, since a large part of our knowledge of the spectra of the stars has been derived in this manner. It happens, however, that nearly all of this very extensive observational material refers only to those portions of the spectrum to which an ordinary photographic plate is sensitive, namely, the blue, violet, and ultra-violet. The lack of observations in the green and yellow and especially in the red is doubtless due principally to the fact that until recently photographic emulsions which were sufficiently sensitive in these regions have not been available. Hence the strong hydrogen line Hα, in the red (wave-length 6563 angstroms) has not been commonly observed in stellar spectra in spite of its great importance in several classes of stars. This line is bright in numerous stellar spectra and in frequent instances is so intense and conspicuous as to be readily shown on photographs having very small dispersion. Moreover, when bright it is subject to change so that stars showing this feature should be photographed at frequent intervals in order that the variations may become a matter of permanent record. At present but little is known in regard to the variations, tho they are apparently of not infrequent occurrence. This spectral line, therefore, appears to be an especially suitable object for investigation with small telescopes.

The photography of the bright Hα in the spectra of numerous stars should present no difficulty with a six or even with a four-inch telescope, if an objective prism of 10° to 30° angle of sufficient size to cover the objective can be secured. The prism should be mounted rigidly in front of the objective with its edge parallel to the celestial equator, in the position of minimum deviation. The only additional adaptation of the telescope required will be an arrangement at the eye end to receive the plate holder.

Unless the observer desires to prepare his own red sensitive plates by staining ordinary emulsions with pinacyanol[1], the Ilford Special Rapid Panchromatic plates are recommended. These plates may be made several times more sensitive by the following process:

At a temperature of about 68° F., soak the plates for four minutes in

Water	75 cc.
Ethyl alcohol	25 cc.
Ammonia	4 cc.

then dry rapidly with an electric fan. If kept cool and dry these plates will remain in good condition for several weeks; under ordinary conditions they will keep for several days or a week. Good results can probably be obtained with an ammoniating bath with the alcohol omitted, especially if the air is warm and dry.

For the photography of the portion of the spectrum containing the red line of hydrogen the ordinary visual objective will, of course, be better than the so-called photographic objective which is corrected for the blue and violet rays. Good results, however, have been obtained by Mr. Humason and the writer in photographing the Hα line with a 10-inch photographic telescope. On another page in this number of the PUBLICATIONS is a list of stars in which we have discovered a bright Hα line. Figures 2, 3, 4 and 5 show the appearance of some of the spectra photographed with this instrument. The steep color curve allows only a very small section in the red to be in good focus. We have tried to make the focal setting so that Hα will occupy the center of this region. The yellow, green, and blue are badly out of focus, but in the ultra-violet the focus again becomes good so that lines near the head of the hydrogen series are well shown. It is interesting that these ultra-violet hydrogen lines are absorption lines while Hα, in the same series, is an emission line. With a visual telescope Hα and Hβ (in the blue green) can be photographed in good focus at the same time. With a reflector, especially interesting spectrograms can be obtained, as the whole spectrum will be in focus. Figure 1 is made from a plate obtained with a reflector.

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[1] For laboratory methods of preparing red sensitive plates, consult *Circular of the U. S. Bureau of Standards*, "Color Sensitive Photographic plates," Nov. 16, 1919.

Some of the brighter stars of Class B which have bright hydrogen lines are listed below:

	R. A. 1900	Dec. 1900	Mag.
γ Cassiop	$0^h50^m.7$	+60°11′	2.2
φ Persei	1 37 .4	+50 11	4.2
ψ Persei	3 29 .4	+47 51	4.3
Alcyone	3 41 .5	+23 48	3.0
c Persei	4 1 .4	+47 27	4.0
ζ Tauri	5 31 .7	+21 5	3.0
α Columbae	5 36 .0	−34 8	2.8
κ Can. Maj	6 46 .1	−32 23	3.8
κ Draconis	12 29 .2	+70 20	3.9
η Centauri	14 29 .2	−41 43	2.6
χ Ophiuchi	16 21 .2	−18 14	4.8
P Cygni	20 14 .1	+37 43	4.9
π Aquarii	22 20 .2	+ 0 52	4.6
β Piscium	22 58 .8	+ 3 17	4.6

A valuable program would be to photograph the Hα line in the above stars at intervals of one or two months. This procedure should in time lead to the detection of any changes which may occur, whether progressive or recurring. If no difficulty is found in photographing the Hα line in these stars, the observations may be extended to fainter stars with a bright Hα. Exposures may be made on moonlight nights without the fogging usually caused by the sky-light, by placing a red color filter in front of the plate. The Eastman A and F gelatine filters have been found satisfactory for this purpose.

Another interesting investigation would be the classification of M-type stars according to the intensities of bands in the extreme red, at wave-lengths approximately 7060 and 7600 angstroms. This would require the use of plates sensitized with dicyanin[2].

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[2] *Scientific Papers of the Bureau of Standards*, No. 318, "Application of Dicyanin to the Photography of Stellar Spectra." April 6, 1918.

Fig. 1

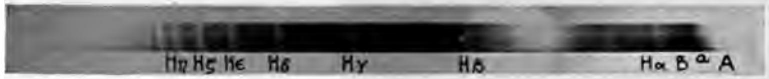


Fig. 2

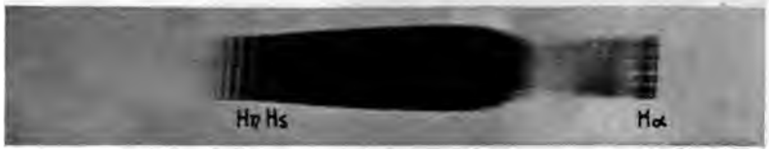
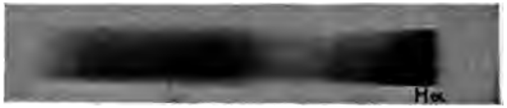


Fig. 3

Fig. 4



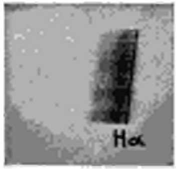


Fig. 5

PLATE X

Descriptions of Illustrations

Figure 1. *α Canis Majoris* (*Sirius*), R. A. $6^h40^m.7$ Dec. $-16°34'$, magnitude -1.6, 1917 Feb. 16.

With 15° objective prism of 9 x 11 inches aperture on the two-foot reflector of the Harvard College Observatory. Emulsion, Seed 27 sensitized with dicyanin A.

Figures 2, 3, 4, 5. With 15° objective prism on the 10-inch Cooke telescope of the Mount Wilson Observatory.

Figure 2. *β Piscium*, R. A. $22^h 58^m.8$ Dec. $+3°17'$, magnitude 4.6. 1919 Aug. 4. Exposure 46 minutes. Emulsion, Seed 23 sensitized with pinacyanol. The Hα line is bright, while the ultraviolet hydrogen lines are dark.

Figure 3. *Nova Cygni*, R. A. $19^h55^m.8$, Dec. $+53°21'$, magnitude 3.7. 1920 Aug. 30. Exposure 15 minutes. Emulsion, Ilford Special Rapid Panchromatic hyper-sensitized with ammonia. The narrow vertical line is the image of the bright Hα line formed by allowing the spectrum to drift rapidly across the plate. Negative by Mr. Humason.

Figure 4. H D 19243, R. A. $3^h0^m.7$, Dec. $+63°7'$, magnitude 6.5. 1920 Sept. 10. Exposure 110 minutes. Emulsion, Ilford Special Rapid Panchromatic hyper-sensitized with ammonia.

Figure 5. H D 20336, R. A. $3^h11^m.2$, Dec. $+65°17'$, magnitude 4.9. 1920 Oct. 25. Exposure 130 minutes. Emulsion, Seed 23 sensitized with pinacynol. Negative by Mr. Humason.

The coordinates given above are for 1900.0.

ERIC DOOLITTLE

1869-1920

By R. G. Aitken

Our sorrow over the death of a colleague or friend whose years have reached or exceeded the allotted three-score and ten is tempered by the reflection that he was given the opportunity to see the fulfilment of his plans for his life's work. In the case of Eric Doolittle, who died on September 21 of the present year, at the age of fifty-one, our sorrow has no such mitigation. Fruitful as his labors had been, we had every reason to expect that those of the coming decade or two would yield results of even greater value to astronomy, for it was known that he had in mind plans for a large program of work for whose execution he was specially fitted by his ability and experience. It is an irreparable loss that he was not permitted to live to carry out his plans.

Born on July 26, 1869, Eric Doolittle lived practically his entire life in the atmosphere of an astronomical observatory; for his father, the late Professor C. L. Doolittle, was appointed professor of astronomy and mathematics at Lehigh University in 1875, and held that post until 1895, when he became professor of astronomy at the University of Pennsylvania and director of the Flower Observatory. Eric received the degree of Civil Engineer from Lehigh University in 1891 and after two years' experience as instructor in astronomy at that university and at the State University of Iowa, went to the University of Chicago for two years' graduate studies in astronomy. Here he proved his capacity as a student of theoretical astronomy and began the laborious researches which resulted in the publication, in 1912, of his memoir on *The Secular Variations of the Orbits of the Four Inner Planets.*

In 1896 he accepted the position of instructor in astronomy at the University of Pennsylvania and became his father's assistant at the newly founded Flower Observatory, taking full charge of the work with the excellent 18-inch refracting telescope. In 1912 he succeeded his father as director of this observatory and as professor of astronomy in the university, the position he held at the time of his death.

Eric Doolittle possessed unusual working powers. He carried a full schedule of work as a teacher in the university—a working program which would satisfy the average man—and in addition to this his record as an observer is one with which a man giving his entire time to observatory work might well be content. Finding the 18-inch telescope and the atmospheric conditions at the Flower Observatory well adapted to micrometric work, he took up the study and measurement of double stars and soon made himself an authority in this field of research.

In 1901 he published his first volume—*Measures of 900 Double and Multiple Stars.* This was followed in 1905 by his *Measures of 1066 Double and Multiple Stars;* in 1907 by his *Catalogue and Remeasurement of the 648 Hough Double Stars;* and in 1914 by his *Measures of 1954 Double Stars.* The thousands of measures accumulated since 1914 and still unpublished will fill at least one more large volume.

Doolittle's work thruout was characterized by its attention to details and its great accuracy, and it was these qualities, as well as his great knowledge of the subject, that led Professor Burnham of the Yerkes Observatory to turn over to him, on his retirement in 1913, the data he had himself accumulated for the extension of his General Catalogue of Double Stars (known as *Burnham's* or β's *G. C.*) with the request that he carry the work to completion. Professor Doolittle accepted this additional responsibility and entered upon the work with his accustomed quiet enthusiasm. His collection of all published observations was so complete and kept so well up to date and was so fully supplemented by his own measures that in recent years he was the authority to whom astronomers all over the world appealed for information concerning any double star in the northern sky.

Notwithstanding all these professional labors, he found time to contribute many popular articles to the newspapers of Philadelphia and to other journals and to take his full share of the ordinary duties of life in a university community. A man of attractive personality, distinguished particularly by his kindly disposition and the genuineness of his nature, he had a wide circle of friends. Never a very strong man physically, his health was seriously impaired some time ago by an attack of influenza. Heart disease developed and since June 24 he had been confined to the university hospital.

In 1902 Eric Doolittle was married to Sara Bitler Halliwell, of Bethlehem, Pennsylvania, and Mrs. Doolittle and a brother, Alfred Doolittle, professor of astronomy at the Catholic University of Washington, D. C., survive him. Memorial services in his honor were held at the University of Pennsylvania on Friday evening, November 12, addresses being made by Dr. Frank Schlesinger, president of the American Astronomical Society, Provost Edgar F. Smith, of the University of Pennsylvania, and the Rev. Robert Norwood, pastor of the Presbyterian Church, with which Professor Doolittle was connected.

OBITUARY NOTICE OF JOHN NELSON STOCKWELL OF CLEVELAND, OHIO

By T. J. J. See

In the death of Professor John Nelson Stockwell of Cleveland, Ohio, May 18, 1920, in the 89th year of his age, America has lost one of her foremost philosophers and the dean of the group of eminent astronomers which originally included Gould, Hall, Newcomb, and Hill. Dr. Stockwell was born on a farm near Northampton, Mass., April 10, 1832, but his parents—William Stockwell III, and Clarissa Whittemore Stockwell, who had been married May 19, 1826—with their five children, moved to Ohio in the autumn of 1833. The future astronomer was the youngest of these children, and was of frail constitution till his fourteenth year, after which he became robust. As his parents were poor, he grew up after his eighth year, with his uncle, Oliver Edgerton, at Brecksville, near Cleveland, Ohio, with which city he was always associated.

Stockwell's early educational opportunities were limited by the undeveloped state of the schools of Ohio, so recently carved out of the great Northwest Territory. But by good fortune common school books fell into his hands, and at twelve years of age his intellectual interest began to assert itself. From the study of arithmetic he passed to algebra, geometry and astronomy. By the accounts given in popular treatises on astronomy, he was led to acquire in 1852 Bowditch's translation of Laplace's *Mécanique Céleste*, which fixed his career in mathematical astronomical research. It will be remembered that Dr. Bowditch had published this great work in 1838-9 at an enormous personal sacrifice, but it was likewise of the greatest inspiration to such astronomers as Hall, Newcomb and Hill. Thus for nearly a century it fixed the careers of the leading American astronomers; and in 1840 Bowditch's edition of Laplace influenced the French Chamber of Deputies to republish the chief works of Laplace, when Madame Laplace was on the point of disposing of a small property, to secure means for this purpose—as mentioned by Arago in his eulogy on Laplace.

Dr. Stockwell was closely associated for forty-two years with Dr. B. A. Gould, who published many of his researches in the *Astronomical Journal;* but he also made numerous contributions to the *Observatory*, the *American Journal of Science*, *Science*, and *Popular Astronomy*. The well known *Memoir on the Secular Variations of the Eight Principal Planets*, was published in the *Smithsonian Contributions to Knowledge*, 1873, on the recommendations of Newcomb and Hall. It had been begun about 1858, but was much delayed, owing to the civil war, and finally was completed under the patronage of Mr. Leonard Case, 1872. Mr. Case became celebrated as the founder of the Case School of Applied Science, Cleveland, in which Dr. Stockwell was the first professor of mathematics and astronomy, 1881-1888, when he gave up teaching to devote all his time to research. Mr. Case also aided Dr. Stockwell in his *Theory of the Moon's Motion*, Phila., 1875, 3rd. edition, 1881. This Theory was a development of much interest, yet it led to some differences with Hill, Adams and other geometers in regard to the method of calculating the motion of the lunar perigee, which has presented difficulties since the time of Newton and Clairault.

In later years Dr. Stockwell made extensive researches on eclipses since the year 3784 B. C. and developed methods for using them as checks on the reckoning in chronology. And in the 88th year of his age he published a new method with elaborate tables for attacking the problem of the ocean tides, which marks a notable practical advance. At the same age he communicated to the writer a notable improvement on Hill's Method for finding the *Maximum Lunation*, which will shortly appear in the *Astronomische Nachrichten*, where it will be generally accessible to astronomers.

Dr. Stockwell was married December 6, 1855, to Miss Sarah Healy, and to this happy union—only broken in 1916 by her death, after sixty-one years of devotion—six children were born—five boys and one girl. Two sons died, one in 1883, the other in 1884, but otherwise the children survive and are highly respected citizens of Cleveland, Ohio, and of the state of Kansas. Always of mild and gentle manner, Dr. Stockwell was much beloved, and his record of devotion to pure science for seventy years, is one which has left a lasting impression on his time.

September 30, 1920.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1921

MALCOLM MCNEILL

PHASES OF THE MOON, PACIFIC TIME.

New Moon	Jan. 8,	$9^{h}27^{m}$ P.M.	New Moon	Feb. 7,	$4^{h}37^{m}$ P.M.
First Quarter	“ 16,	10 31 P.M.	First Quarter	“ 15,	10 53 A.M.
Full Moon	“ 23,	3 8 P.M.	Full Moon	“ 22,	1 32 A.M.
Last Quarter	“ 30,	12 2 P.M.	Last Quarter	Mar. 1,	6 3 A.M.

Mercury on January 1 is a morning star rising about half an hour before sunrise and is therefore too near the Sun for naked eye visibility. It is moving eastward and passes the Sun on Jan. 16, thus becoming an evening star. It is then some distance south of the Sun and for a day or two rises later and sets earlier. Its eastward distance from the Sun now increases, but remains too small for naked eye view until after Feb. 1. It reaches greatest east elongation on Feb. 15 and then remains above the horizon for about an hour and a half after sunset. It is then an easy naked eye object, and can be seen on clear evenings for a week before and a week after the time of greatest elongation. The duration of visibility is shorter than usual as the elongation is only 18°8′, near the minimum, the planet passing its perihelion only eight hours after reaching greatest elongation.

Venus is an evening star in fine position for evening observation, remaining above the horizon for from three and a half to four hours after sunset. It comes to greatest east elongation from the Sun on Feb. 9. Its distance from that body is then 46°46′. The greatest elongations differ only slightly as the orbit is nearly circular, whereas the greatest elongations of *Mercury* differ as much as 50%, the orbit being very eccentric. During the two months the planet moves 56° eastward and 28° northward from *Capricorn* thru *Aquarius* into *Pisces*. It passes the Vernal Equinox on Feb. 2. During the winter months *Venus* will be very bright, far brighter than the other planets, the maximum being reached about the middle of March, half way between the times of greatest elongation and inferior conjunction. Its stellar magnitude will then be -4.3. On Jan. 1 it is only about half a magnitude fainter. During the latter part of February it will be bright enough for naked eye observation in full sunlight. *Venus* passes conjunction with *Uranus* on Jan. 9, with *Mars* also on the same date, the least distance between the planets being rather less than the Moon's apparent diameter. It also passes conjunction with the Moon on the evening of Feb. 11, and for certain parts of the Earth the planet will be occulted. The prediction of a planet's occultation by the Moon for any particular place on the Earth is nearly as intricate a computation as is the prediction of a solar eclipse, a very similar problem.

The year 1921 is a poor one for observations of *Mars*, as it is in the part of its orbit farthest away from the Earth, consequently fainter. It remains an evening star up to the end of June and will be a morning star for the rest of the year. However it will be bright enough and remain far enough away from the Sun for easy visibility until possibly the end of April. During January and February it will not set until about three hours after sunset, the interval diminishing about half an hour during the two months. The planet is moving eastward and northward among the stars in the neighborhood of *Venus*. The conjunction with the latter, on Jan. 9, has already been mentioned. Both planets are moving eastward, *Mars* a little less rapidly than *Venus*. On Jan. 1 it is about 3° east of *Venus*, and at the end of February *Venus* is about 10° east of *Mars*. The actual distance of *Mars* from the Earth is increasing, being at the end of February about double the Earth's distance from the Sun. Its brightness on Jan. 1 is a little less than that of a standard first magnitude star, and during the two months it will diminish a little, but it will still be an easy object for naked eye observation.

On Jan. 1 *Jupiter* and *Saturn* both rise late in the evening, the former a little after 10 P. M. and the latter somewhat before 11 P. M. By the end of February *Jupiter* rises shortly after 6 P. M. and *Saturn* a little more than half an hour later. During the autumn of 1920 both planets have been moving eastward among the stars; but *Jupiter* on Jan. 4, and *Saturn* on Jan. 5 reach their stationary points and begin their westward or retrograde motion. Both planets are then in the eastern part of the constellation *Leo*, *Jupiter* being about 6° west and 1° north of *Saturn*. The common westward motion will continue until late in the spring with *Jupiter* moving a little faster than *Saturn*. The apparent distance gradually increases and reaches 9° by the middle of the spring. During May both planets cease to move westward and begin their eastward or direct motion. The apparent distance now decreases and on Sept. 14 the planets come to conjunction, *Jupiter* passing 1°2′ south of *Saturn*. Unfortunately at this time the planets are too close to the Sun for naked eye view, and come to conjunction with the latter about a week later.

Saturn's rings are not at all conspicuous during the year, the Earth and Sun being nearly in their plane, and until late in the year it will take a good telescope to show them. The Earth passes thru this plane late in February.

Uranus is an evening star during January but is rather too near the Sun for good naked eye view. The Sun's westward motion causes a rapid approach to the planet, conjunction being reached on Feb. 24.

Neptune is in almost exactly opposite position to *Uranus* in the sky, coming to opposition with the Sun on Feb. 1. It is in the constellation *Cancer*, but can not be seen without a telescope.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE ORBITS OF THE SPECTROSCOPIC COMPONENTS OF BOSS 4602

This star ($\alpha = 18^h\ 07.5m$, $\delta = +79^\circ 59'$, photographic magnitude 6.6, type F5) is one of the first twelve binaries discovered at the Dominion Astrophysical Observatory at Victoria, B. C., the announcement of which appeared first in the *Journal of the Royal Astronomical Society of Canada* for November 1918.

Dr. J. S. Plaskett secured five plates of the star, in the program of radial velocity determinations, between June 19 and July 21, 1918. His measures of these five spectrograms revealed the binary character of the star. Between July 1, 1919, and September 18, 1919, 28 plates were secured. All of these, as well as those secured by Dr. Plaskett in 1918, were measured on the Hartmann Comparator, using a sky or a Mars standard.

From the measures of the first 14 or 15 of the 1919 plates, together with Dr. Plaskett's measures of 1918, the period was found to be very close to 10.5 days. This made it possible to get the remaining plates well distributed along the velocity curve. The velocities did not, however, agree well with any elliptic curve, altho those at nearly the same phase showed as reasonable agreement as was to be expected. Measures of a plate secured on September 12, 1919, on the Hartmann comparator proved an exception to this rule and a closer examination of the plate revealed close companion lines to at least ten of the lines. A re-examination of all of the previous plates, including those secured by Dr. Plaskett in 1918, showed that on seven of these plates from four to ten lines showed double. Since the lines of the two components are just separable, for one-prism dispersion, and besides this, only those lines which are most intense show at all for the secondary component, it is easy to see why they were overlooked on the few plates on which from two to ten show at all.

The writer had to leave Victoria on September 18, 1919, to resume his duties at the University of Washington and bad weather prevented securing more plates, at phases which would show the double lines, before October 15, and after that it was inadvisable to attempt to get any more plates in 1919, owing to the unfavorable position of the star for observation. However, in April, 1920, Mr. Harper and Dr. Plaskett kindly secured three more plates at such phases as to show the lines double. Again in August, 1920, four more plates were secured at such phases as to show some of the lines double. Sixteen plates in all were therefore secured which show double lines and the orbit is based entirely on the measures of these sixteen plates. The remaining twenty-six plates were measured on either the Hartmann comparator or the Gaertner Measuring Machine or on both, but none of these measures was used in the final computations for the orbital elements. The unused measures exhibit the usual behavior of lying nearer the gamma line, being almost on the gamma line for nearly a day near the points where the two velocity curves intersect.

The lines of the secondary component are quite faint, whereas those of the principal component are rather diffuse and much more numerous. The probable error of a plate for the principal component is ±2.36 and for the secondary ±4.65 km. per second. The mass of the secondary component is 0.903 times that of the principal component.

From the preliminary elements given, observation equations were built up according to the notation of Lehman-Filhes, modified to suit the case of double spectra and a least squares solution

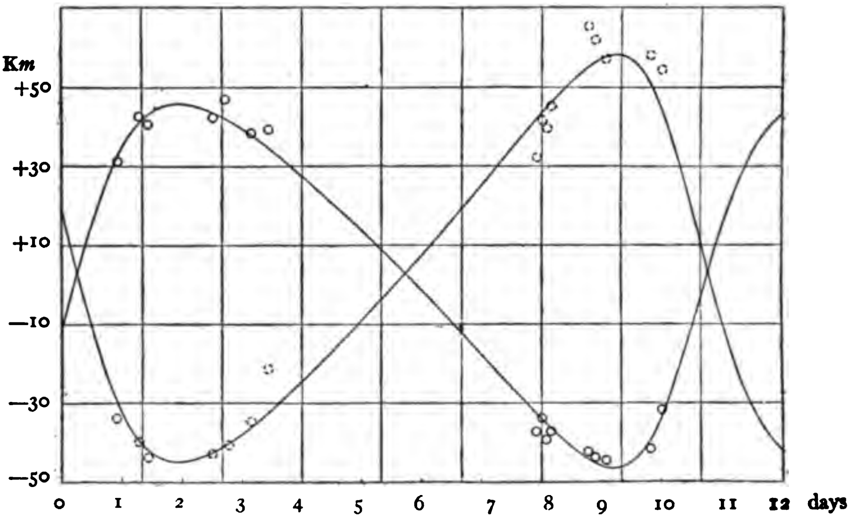


FIG 1. RADIAL VELOCITY CURVES OF BOSS 4602 SHOWING INDIVIDUAL OBSERVATIONS.

effected. Since the observations extended over parts of three seasons, the period was also included in the solution. This necessitated treating all the observations separately.

The least squares solution gave corrections to the preliminary elements, as given in the following table. One solution was deemed to be all that was warranted from the data at hand, as judged by the fair agreement of the final ephemeris residuals with those obtained by substitution in the observation equations. The sum of the squares of the residuals for the observed places was reduced from 1757 to 1082 or about 38 per cent.

TABLE OF ELEMENTS

ELEMENT	PRELIMINARY	FINAL	
Period................P	10.527 days	10.5217	±0.0018 days
Eccentricity...........e	0.30	0.314	±0.014
Longitude of apse......ω_1	270°	256°.76	±4°.38
Longitude of apse......ω_2	90°	76°.76	±4°.38
Velocity of system......γ	+1.88 km. per sec.	+2.93	±0.62 km. per sec.
Semi-amplitude primary.K_1	47 km.	46.16	±0.83 km.
Semi-amplitude secondary.........K_2	50 km.	51.50	±1.32 km.
Periastron passage......T	J.D. 2,421,764.592	J.D. 2,421,764.6481	±0.1112
Semi-major axis...$a_1 \sin i$		6,341,000 km.	
Semi-major axis...$a_2 \sin i$		7,074,000 km.	
Mass primary....$m_1 \sin^3 i$		0.457 ●	
Mass secondary..$m_2 \sin^3 i$		0.413 ●	

The graph shown represents the velocity curves using the final elements. Individual observations are plotted. An interesting problem, reserved for the future, will be to re-determine these orbits from plates obtained with higher dispersion.

I wish here to express my appreciation of the kindness shown me by Dr. Plaskett and all the members of his staff at the Dominion Astrophysical Observatory at Victoria during my stay at the Observatory for twelve weeks of the summer of 1919 and six weeks of the summer of 1920. Every possible facility was extended to aid me in the prosecution of the work on Boss 4602 and on other spectroscopic binaries on which I am working, the results of which work will appear as soon as completed.

University of Washington,
Seattle, Wash.,
Oct. 1, 1920.

S. L. Boothroyd.

Determination of the Solar Parallax from Spectroscopic Observations of Venus

Observations of wave-lengths in the spectrum of *Venus* have been made at Mt. Wilson during the last two elongations for the purpose of checking Evershed's results.[1] A detailed account of the observations, with a discussion of them as related to Evershed's hypothesis of an "Earth-effect," will appear soon in the *Contributions of the Mount Wilson Observatory*. In reducing these observations for wave-lengths the relative velocity of *Venus* with respect to the Earth and Sun must necessarily be taken into account. This involves the value of the solar parallax and, as has been pointed out before, furnishes a method of determining that constant[2].

Spectroscopic observations for solar parallax promise to furnish determinations comparable to other methods in precision. Their value lies in the probably compensating character of the errors inherent in different methods. For a star near the ecliptic the Doppler displacements are about twice as great as those observed for *Venus*, but in the case of *Venus* the greater brightness of the object allows the use of higher dispersion. In either case long series of observations are possible, making for low probable errors. The number of stars available gives added weight to stellar observations, but the lack of knowledge of conditions that may affect the displacements of the spectral lines in individual stars introduces uncertainties.

In 1905 Küstner published the results of his spectrographic observations for solar parallax, in which he used *αBootis* and obtained the value of $\pi = 8''.829 \pm 0''.013$[3]. Probably the best spectroscopic determination is that obtained at the Royal Observatory, Cape of Good Hope[4], the detailed account of which is summarized by A. B. Turner in these PUBLICATIONS for October, 1912.

Our observations were made with the Snow telescope in connection with a Littrow grating spectrograph. The diameter of *Venus* varied from 1.3 to 3.3 mm. The slit was 0.05 mm. wide, its position in general being approximately normal to the terminator. The spectrograph as used gives a linear dispersion of 3A per mm. Altho the grating was very bright in the first order, exposures of about one hour were necessary. Exposures were made upon the iron-arc simultaneously with exposures upon *Venus* or the sky. The wave-lengths of thirty lines in these spectra were measured and reduced by identical methods and the observed differences between wave-lengths in the *Venus* and sky spectra were made the basis of the investigation.

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[1] *The Observatory*, **42**, 51, 1919.

[2] *Publ. A. S. P.*, **19**, 196, 1907.

[3] *A. N.* 4048-4049, 1905.

[4] *Annals of the Cape Obs.* **10**, Part 3, 1909.

Differences between the observed and computed velocities of *Venus* might be caused by a rotation of the planet, unless special precautions have been made to eliminate that effect; but the spectroscopic observations of Slipher[5] furnish very definite evidence of a long rotation period and it seems much more probable that such differences should be attributed to an erroneous solar parallax. Our spectrograms were not measured for inclinations of the lines, but the slight astigmatism of the grating was such that it is doubtful whether rotation of the planet would have been shown in this way, even if the guiding and seeing had been perfect. Altho rotation of the planet produces equal and opposite velocity displacements at the limb and terminator[6], the distribution of velocity over the disk is such that the integrated effect is not zero. A computation of the effect of rotation in producing displacements requires assumptions which are very uncertain, but if the rotation period of *Venus* is of the same order as its period of revolution the error introduced by neglecting the rotation can not affect the solar parallax by a thousandth of a second.

Plates taken at high and low altitudes on several nights showed that the measured wave-lengths were systematically shorter for the lower altitude in both morning and evening observations. After eliminating from all the observations the effect of altitude, which is well represented by the empirical equation $\Delta\lambda . 10^{-3} = 1.5 - 1.0 \cot h$, there still remained slight systematic displacements to the violet which could be correlated with the relative position of Earth, *Venus*, and Sun. These are well represented by any one of the following equations:

$$\Delta\lambda . 10^{-3} = +1.5 - 3.0\,(1 - \cos \mathrm{VSE})$$
$$\Delta\lambda . 10^{-3} = +0.8 - 3.5 \cos i$$
$$\Delta\lambda\ 10^{-3} = -2.8 + 0.28 R$$

where VSE is the angle *Venus*—Sun—Earth, i is the phase angle of *Venus*, and R the semi-diameter in seconds of arc. These two types of displacement are no doubt similar to those experienced by other observers and must be eliminated before the results can be used for parallax determinations. Since they have the same sign in morning and evening observations, and the effects of an erroneous value of the parallax appear with opposite signs, it is possible to eliminate the systematic errors by combining the means of the two series, provided the conditions of observations are the same in both.

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[5] *Lowell Obs. Bull.*, **1**, 9, 1903. Bull. No. 3.
[6] *The Observatory*, **42**, 308, 1919.

In our observations these conditions were not exactly fulfilled and the observed difference of 0.0012A between the means of the two series was reduced to 0.0006A when the observations were corrected by applying the empirical equations referred to above. The mean wave-length of the lines measured was λ4500, so that this 0.0006A is equivalent to a difference between the observed and computed velocity of 0.04 km. per sec. for the two series. In all, 56 *Venus* plates were measured, the probable error for a single plate being ±0.20 km. The calculated correction to the adopted solar parallax of 8″.80 is +0″.013±0″.017.

The corrections deduced by Hinks from the photographic observations of *Eros* range from +0″.014 to −0″.035 for different observers, his adopted value being +0″.007±0″.0027[1]. In the spectroscopic determination at the Cape of Good Hope the corrections obtained from individual stars varied from +0″.035 to −0″.036, the adopted parallax being 8″.800±0″.006. The parallax deduced from our *Venus* observations is a by-product from spectrograms taken for other purposes; since it falls well within the range shown by other determinations, it is probable that a very reliable parallax could be obtained from a program of observations planned for the purpose.

Charles E. St. John,
Seth B. Nicholson.

The Planetary Disks of Nova Aquilae No. 3

Slitless spectrograms and visual observations of *Nova Aquilae* No. 3 with the 100-inch reflector show very distinct markings within the Hα and N_1N_2 disks. On September 9, visual observations at the primary focus, with seeing 6 on a scale of 10, showed a bright bar crossing the nebular disk in p. 40°, approximately. The spectrograms made the same night show a short bright line crossing the center of the N_1N_2 disk, extending more to one side than the other. On September 10 the seeing averaged about 2, but at moments of better seeing the bar was easily observed.

On October 5, at the Cassegrain focus, with seeing 3, slitless spectrograms of 2, 6, and 10 minutes exposures were obtained with a focal plane spectrograph, the focus being intermediate between red and blue-green. A strong continuous spectrum appears, crossed by heavy Hα and nebular disks which show much detail. The nebular disk appears longer N-S, but its form may be influenced by the continuous spectrum; the Hα disk, tho circular in outline, somewhat resembles a dumbbell. The bar in general resembles an S-shaped line twisted about the N-S axis; its brightest part is a central line in p. 40° roughly, extending from about $0'.5$ on the preceding side of the center to $1'$ on following side, and having a wisp on its following end.

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[1] *M. N.*, **67**, 70, 1906.

The continuous spectrum is stronger across the disk, knots appearing at the points of intersection with the periphery. The Hα disk is ill-defined on the preceding and following sides, and the nebulosity is concentrated more on the south side.

F. G. PEASE.

PARALLAXES OF TWO CEPHEIDS

The parallaxes of two Cepheid variables, RX *Aurigae* and RR *Lyrae*, were recently determined from 16 and 20 exposures, respectively. The results are:

RX *Aurigae*....... $\pi = -0''.001 \pm 0''.005$
RR *Lyrae*.......... $\pi = +0''.006 \pm 0''.006$

The photometric parallaxes, according to Shapley, are $+0''.0006$ and $+0''.0030$, respectively.

Adams finds that the spectroscopic parallax of RR *Lyrae* is $\pi = +0''.004$. Taking the mean of the three values of its parallax, we find the absolute magnitude is 0.0 at maximum and +0.9 at minimum. The velocity at right angles to the line of sight is 243 km./sec.; the radial velocity is 50 km./sec., giving a total velocity of nearly 250 km./sec., an extraordinary value for an object of high luminosity.

A. VAN MAANEN.

PARALLAX OF A FAINT STAR WITH LARGE PROPER MOTION

In the issue of this journal for December, 1918, I announced the discovery of a star of mag. 13.2 and proper motion $0''.377$; its position for 1900 is $\alpha = 4^h53^m11^s$, $\delta = +39°13'$. It was measured as a comparison star for deriving the parallax of Boss 1182, but was later rejected for this purpose on account of its large proper motion and presumably large parallax. A series of 16 exposures has now been measured, with a resulting parallax of only $+0''.010 \pm 0''.005$, indicating an absolute magnitude of +8.2 and a velocity at right angles to the line of sight of about 180 km./sec.

A. VAN MAANEN.

TEN STARS OF CLASS B HAVING THE Hα LINE BRIGHT

On objective prism photographs secured with the 10-inch Cooke telescope, the Hα line of hydrogen has been observed as an emission line on the dates indicated, in the stars in the following list. The general appearance of these spectra on the 10-inch plates is well illustrated by Figures 2, 4, and 5 of Plate X. The observations marked "100-inch" or "60-inch" are made in the usual photographic spectral region, with a single-prism slit spectrograph attached to the 100-inch or to the 60-inch telescope. One or more of the hydrogen lines Hβ, Hγ, and Hδ is shown by these slit spectrograms to be bright, or to consist of bright portions situated within a wider dark line, possible exceptions being HD 698, in which Hβ is peculiar but probably has a bright portion, and ε *Piscis Australis* in which the bright portions of Hβ, if present, are weak and indistinct.

Star	R. A. 1900	Dec. 1900	Spect.	Mag.	Date		Observer
HD 108......	$0^h\ 0^m.9$	+63° 7′	B	7.4	1920 Aug.	11	H
					"	29	H
					"	28	M 100-inch
					Oct.	26	M 100-inch
					"	27	M 100-inch
HD 698......	0 6 .3	+57 39	B5	7.1	1920 Aug.	11	H
					Sept.	1	H
					Oct.	28	M 100-inch
HD 7636.....	1 11 .2	+57 6	B1	7.6	1919 Aug.	5	M
					1920 Aug.	13	H
					Sept.	12	M
					"	18	H
					"	28	M 100-inch
HD 12882....	2 1 .1	+64 33	B3	7.5	1920 Sept.	18	H
					Oct.	25	H
HD 19243....	3 0 .7	+62 0	B0	6.5	1919 Oct.	1	M
					"	2	M
					1920 Sept.	10	M
					"	28	M 100-inch
9 Camelopardalis..	4 44 .1	+66 10	B0	4.4	1920 Oct.	4	H 2 plates
					"	8	H
					"	25	H
					"	26	H
HD 37115....	5 31 .0	− 5 41	B5	8.2	1920 Sept.	18	H
					Oct.	28	M 100-inch
HD 45995....	6 25 .6	+11 19	B0	5.8	1920 Mar.	6	H
					"	7	H
					Oct.	26	M 100-inch
HR 8009.....	20 50 .6	+40 19	B8	6.5	1920 Sept.	11	M
					"	12	M 2 plates
ε Piscis Australis..	22 35 .1	−27 34	B8	4.2	1919 July	1	M
					Aug.	4	M
					"	8	M 60-inch
					1920 Sept.	10	M
					"	28	M 100-inch

NOTES

HD 108 Remark in HD, "The spectrum appears to be nearly continuous. The dark lines are faint and show very slight contrast compared with the other portions. Bright spaces or lines are suspected. The class may be Oe5." Our plates show that this spectrum is of special interest. The hydrogen lines are bright with a dark portion on the more refrangible side, and numerous other bright lines are seen. The spectrum somewhat resembles that of P *Cygni*. A more complete description will be published in the *Contributions* from the Mount Wilson Observatory.

HD 698 Hβ is peculiar, a bright portion apparently occupying an unsymmetrical position within a wider dark line.

HD 7636 Remark in HD: "Hβ is not distinctly seen."

9 Camelopardalis This star is a spectroscopic binary having sharp H and K lines, whose displacements have been discussed by O. J. Lee[1].

HD 37115 This is the brighter star of the double, Burnham 2850.

ϵ *Piscis Australis* The slit spectrograms taken on 1919 Aug. 8 and 1920 Sept. 28 show that Hβ is essentially an absorption line, altho it may contain very weak bright portions.

Paul W. Merrill,
Milton L. Humason.

Summary of Mount Wilson Magnetic Observations of Sun-Spots for September and October, 1920

Since the sun-spot maximum in 1917 the decline in spot activity has been more rapid than the average. August and September were especially quiet, the four successive spotless days in September being the longest calm period since the summer of 1915. The marked increase in spot activity during October and the last week in September will bring the number of sun-spots up to nearly the normal value for this phase of the spot cycle.

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[1] *Astrophysical Journal*, **37**, 1, 1913.

MAGNETIC CLASSIFICATION OF SUN-SPOTS FOR SEPTEMBER, 1920.

No.	C. M. P.	Lat.	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1737	Sept. 2.4	−14	30	βp	β	β	β	β	β	β	x	x						
1738	1.7	−13	11	βf	αf													
1739	1.9	+14	7				βp	βp	αp	x								
1740	Aug. 31.9	−11	3					β										
1741	Sept. 12.6	−13	23								x	β	βγ	βγ	βγ	βγ	γ	γ
1742	10.2	+ 9	24												βf	βf	β	β
				2	2	1	2	3	2	2	2	2	1	1	2	2	2	2

No.	C. M. P.	Lat.	H	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1742	Sept. 10.2	+ 9	24	x														
1743	26.9	−10	19						x	αp	αp		αp	αp	αp	αp	αp	αp
1744	28.1	−12	26							x	βp		βp	βp	βp	βp	αp	αp
1745	27.9	+21	x							x								
1746	23.9	+15	16										β	βp	βp	βp	βp	x
1747	29.4	−14	25										αp	αp	αp	βp	βp	βp
1748	28.7	−15	10										βf	βf	β	βp	αp	
1749	29.5	+14	29												β	βp	βp	βp
1750	Oct. 6.6	+ 8	23															x
				1	0	0	0	0	1	3	2	—	5	5	6	6	6	6

NOTES.

No. 1741 A stream of spots in which the polarities were distributed as in two regular bipolar groups, with the following members of the first group close to the preceding members of the second. The extreme eastern spots of the group disappeared, leaving a complex group.

No. 1744 The large preceding spot of this group divided, forming two regular spots with negative polarities.

No. 1745 Two very small spots near the east limb, no polarity observations.

No. 1747 A return of No. 1737.

No. 1750 A return of No. 1742.

MAGNETIC CLASSIFICATION OF SUN-SPOTS FOR OCTOBER, 1926.

No.	C. M. P.	Lat.	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1743	Sept. 26.9	−10	19	x															
1744	28.1	−12	26	αp	αp	αp	x												
1747	29.4	−14	25	βp	βp	βp	βp	x											
1749	29.5	+14	29	βp	βp	αp	αp	x											
1750	Oct. 6.6	+ 8	23	αp	αp	βp	βp	x	αp	αp	αp		αp						
1751	Sept. 27.7	−11	10	β	βp														
1752	Oct. 3.1	− 5	11		βf	β	βp	x											
1753	9.5	+ 9	24				β	x	β	β	β		βp	βp	βp	βp	αp	αp	
1754	Sept. 29.6	−10	5				αp												
1755	Oct. 12.5	−16	23						x	βp	βp		βp	βp	βp	αp	αp	βp	x
1756	9.3	+13	12								βp		βp	β	βp				
1757	11.9	+ 9	23										βp	βp	βp	βp	αp	αp	x
1758	16.1	− 7	21														β	βf	β
1759	20.9	+11	12															αp	αp
				6	6	5	7	5	3	3	4	—	5	4	4	3	4	5	4

No.	C. M. P.	Lat.	H	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1758	Oct. 16.1	− 7	21			x	βp	βp										
1759	20.9	+11	12			x	x	x	β									
1760	16.7	− 8	12			x	x	βp	x									
1761	24.0	+19	23			x	β	βf	βf	βp	βγ	βγ	βp	αp		αp	x	
1762	26.5	−14	16					αp	βf	β	β	βf	βf	αf		αf		
1763	24.7	−15	13						βp	βp	βp	βp	βp	βf				
1764	26.4	+17	5										β	αp				
1765	25.5	−16	19										βf	βf		βp	βp	
1766	Nov. 4.4	+11	15													x	x	
1767	5.4	−11	30														x	
				—	—	4	4	5	5	3	3	3	5	5	—	4	4	—

NOTES.

No. 1759 A return of No. 1746.

No. 1761 An extended group, 15 degrees long on some days. The distribution of polarities among the small spots was not always regular.

No. 1762 A return of No. 1747. This was a rather scattered group. No. 1765 developed just ahead of it, after which the preceding spots of No. 1762 disappeared.

ON THE OCCURRENCE IN THE SPECTRUM OF *Nova Cygni* OF THE MOVING DOUBLET NEAR Hδ

The presence in the spectrum of *Nova Cygni* No. 3 of the remarkable pair of dark lines lying on the more refrangible side of the Hδ line, which had been found by Plaskett[1] and by Paddock[2] in the spectrum of *Nova Aquilae* (3), was referred to in a previous note[3]. Among other peculiarities of behavior which the pair developed in *Nova Aquilae* was an irregular movement back and forth along the spectrum. The purpose of the present note is to call attention to its similar restlessness in the spectrum of *Nova Cygni*. The lines are first certainly recognizable in that spectrum on a plate of September 14, which shows them as hazy bands in approximate positions 4064 and 4070A. On subsequent dates their relative positions were as follows:

Sept. 16....same as on Sept. 14.
" 18....slightly displaced toward violet.
" 19....same as on Sept. 14.
" 21....displaced toward red.
" 29....displaced toward violet.

The extreme positions were those of September 21 and 29, when the wave-lengths were:

September 21	September 29
4065.2	4062.2
71.2	68.1

A total range of 3A is shown by the measures. This is less than the variation found in *Nova Aquilae*, but establishes quite certainly the inconstancy of position. On the last two dates the lines were among the strongest in the spectrum and were easily measurable. The positions of the other absorption lines changed very little during the interval.

The identity of the pair with the enhanced nitrogen doublet 4097.4–4103.4 has been suggested by Baxandall[4]. On the basis of this identification the displacements of September 21 and 29 were −32.2 and −35.2A, respectively. In the casual examination of the plates thus far undertaken no other displacements of like amount have been encountered. The displacements of the hydrogen and some of the metallic lines are given in the previous note.

W. H. WRIGHT.

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[1] *Journ. R. A. S. Canada*, **12**, 350, 1918.
[2] *Publ. A. S. P.*, **31**, 54, 1919.
[3] *Ibid* **32**, 275, 1920.
[4] *Publ. A. S. P.*, **31**, 297, 1919.

WARNING TO ASTRONOMERS AND OTHERS

Inquiries have come to me from various parts of the United States concerning the relations of Dr. Augustus Fischer to the Lick Observatory. It appears that Fischer has been asking for financial assistance upon the basis of the alleged fact that he was for many years an astronomer in the Lick Observatory and, in certain cases, that he was acting in accordance with my suggestions. As a warning I would say that Dr. Augustus Fischer is wholly unknown to me. No person of this or similar name has ever been connected with the Lick Observatory.

W. W. C.

GENERAL NOTES

The Warner and Swasey Observatory of the Case School of Applied Science.—Mr. Swasey and Mr. Warner, founders of the well-known firm, The Warner & Swasey Company, have constructed and presented to the Case School of Applied Science, Cleveland, Ohio, a well-equipped observatory. The observatory is admirably located near the eastern edge of the city on a small hill just off Euclid Avenue in a fine residential section. An illustration of the new observatory accompanies this note.

The dome contains a 12-inch equatorial telescope, the objective by Brashear and the mounting by The Warner & Swasey Company. There are three transit instruments, one of them resembling the form used in the work of the International Latitude Association. There are the usual auxiliary instruments, such as clock, chronograph, etc.; a wing on the main floor contains an excellent library; there are photographic rooms in the basement; the building also contains living quarters for the astronomer. The architectural features of the building have been given careful consideration and the materials and construction are of the highest quality.

The Warner & Swasey Observatory was dedicated on October 12, 1920. Appropriate addresses were made by Mr. Swasey, who emphasized the intimate relationships of The Warner & Swasey Company with the many astronomers of the world whom they had supplied with instruments; by Mr. Warner, a trustee of the Case School of Applied Science, in presenting the keys to President Howe of the Case School; by President Charles S. Howe, who spoke in appreciation of the gift and of its purposes; by Director W. W. Campbell of the Lick Observatory, who delivered a formal address on "The Daily Influences of Astronomy"; and finally by Professor D. T. Wilson, of the Case School, astronomer in charge of the observatory, concerning the proposed activities of the new institution.

It is intended that the Warner & Swasey Observatory shall meet the technical needs of the Case School, in the training of engineers, and in the general education of the students; that it shall be available for the advancement of astronomical knowledge in the community; and that a share of its resources shall be applied to research.

The exercises were largely attended by professors and teachers of astronomy and the related sciences located in Ohio and neighboring states.

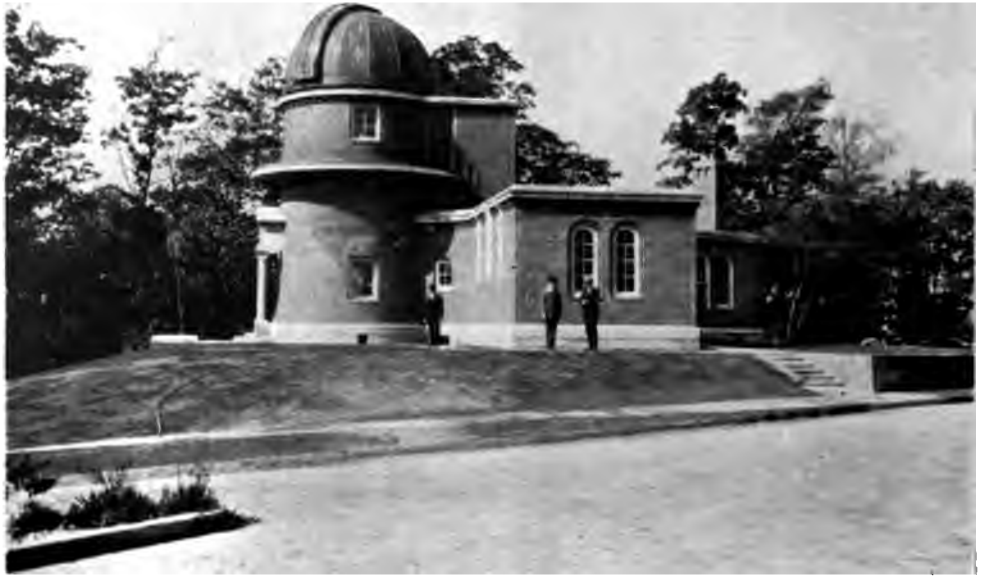

PLATE XI
The Warner and Swasey Observatory, of the Case School

Some Astronomical Howlers.—In a large class in Elementary Astronomy there will be some who have no particular interest in it and consequently obtain confused notions of various parts of the subject. The frantic grasping at straws by these is evidenced in the answers they give in examinations. As these peculiar answers may afford some amusement to the readers of these PUBLICATIONS I have extracted some of them.

From Answers to Questions on Variation of Latitude.

The pole does not always rest in the same place but describes an irregular path about the place where it ought to be.

Latitude is a variable quantity. It increases as you approach the north pole, and decreases as you leave it.

No one latitude on the Earth can be said to be a fixed point.

Küstner of Bonn proved that a disturbance such as an earthquake would tend to throw the pole out of rigidity.

From Answers to Questions on Time.

True solar time is variable to such an extent that we could never keep modern appointments by it.

Mean solar time is gotten by observing the sidereal time when the equator and ecliptic cross, for at this time sidereal and mean time are the same.

From Answers to Questions on Comets.

Comets are great volumes of nothing.

Comets occur in regular ellipses.

A comet is a huge body of substance supposed to be gas whose density is almost negligent.

A comet is nearer a perfect vacuum than any physic laboratory can make it.

Comets seem to shoot from nowhere and go out again into space.

Miscellaneous.

One of the six elements of an orbit is the enclination of eccentricity to horizontal plane.

The asteroids are small planets which seem to have been caused by a large planet being spoiled in the making.

Altitude may be found by using a sexton.

More solar eclipses happen of the Sun than of the Moon.

Bode's Law fails to comply with *Neptune.*

The Earth, upon which we live and spend most of our time is—

Astronomy certainly shows students the absolute nothingness of the Earth.

Neptune is one of the planets to be discovered last.

When a heavier ray of light hits a lighter ray it is moved from its straight path or refracted.

Semi-diameter is the distance of the Sun from one end to the middle.

The ecliptic is the plane of the ellipse that the Sun prescribes in his annual trip around the Earth.

By its appearance at least, the Moon seemed to vindicate the cheese theory.

Students' Observatory, R. T. CRAWFORD.
Berkeley, California.

Gifts to the Society.—Thru the courtesy of Mr. W. A. Clark, Jr., and Dr. Mars F. Baumgardt, the Society has received a large-scale framed photograph of the Moon made from a negative taken with the great Hooker reflecting telescope on Mount Wilson and a radium map of the constellation of *Orion*.

In recording our thanks for the gifts we desire also to call attention to the Clark Observatory, erected on the residence grounds of Mr. W. A. Clark, Jr., at Los Angeles. It is among the finest private astronomical observatories in the country and has an unusual equipment. An illustrated account of it is published by Dr. Baumgardt, the director, in the *Bulletin* of the Southern California Academy of Sciences for July, 1919. In addition to a 6-inch refractor, 8-inch Brashear reflector, coelostat with 10-inch plane mirror, spectroscope and other auxiliaries, and smaller portable telescopes and binoculars, the equipment includes a 2-inch refractor with quartz lens, three stereopticons, a moving-picture machine, elaborate models of the Moon and the planets, globes, photographs, 3000 feet of astronomical motion-picture film, 30 mechanical and more than 1300 ordinary lantern slides from photographs taken at the leading American observatories. Perhaps the most unique feature of the equipment is a series of star maps on which the stars are made luminous by the action of alpha-particles of radium upon a base of sulfide of zinc.

The Twenty-fourth Meeting of the American Astronomical Society[1]—This meeting, held on September 1 to 4, 1920, at Smith College, Northampton, and Mount Holyoke College, South Hadley,

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[1] Reports of this meeting reached the editors too late for insertion in our October issue.

Massachusetts, on the joint invitation of the directors of the two observatories, Miss Harriet W. Bigelow and Miss Anne S. Young, was notable as being the first to be held at a woman's college. Perfect weather conditions and the hostesses' well-planned social program made it also one of the most enjoyable of the Society's meetings. It was appropriate that the attendance should be the largest in the history of the Society.

Altho the *list* of papers was a long one, the papers themselves were, for the most part, commendably short, and time was available for the discussion of many of them. Abstracts will be printed, as usual, in *Popular Astronomy*. At the business meeting reports of committees were received, officers elected, new members admitted and resolutions adopted to meet with the American Association for the Advancement of Science in Chicago in December, 1920.

Sir Frank Watson Dyson, Astronomer Royal, Greenwich Observatory, England, was elected an honorary member of the Society. The Society has only one other living honorary member, Professor J. C. Kapteyn, of Groningen, Holland.

Obituary Notices.—On other pages of the present number will be found notices of the life-work of two American astronomers who have died during the present year. *Science*, for November 5, records the death of another American astronomer, Arthur Searle, Phillips professor emeritus of astronomy at Harvard University, who died at his home in Cambridge, on October 23. His active connection with the Harvard College Observatory extended over the forty-three years from 1869 to 1912, and the *Annals* of the Observatory contain many papers by him, relating chiefly to photometric and meridian circle observations. His largest piece of work was the catalog of 8337 stars between declination $-9^\circ 50'$ and $-14^\circ 10'$ which constitutes one part of the great international catalog of stars to the 9.0 magnitude known as the *Astronomische Gesellschaft Zone Catalogue.*

We regret to have to record also the death, in August of this year, of two prominent European astronomers—Hermann Struve on August 12 and Giovanni Celoria on August 17.

Hermann Struve entered upon his active astronomical career in 1883 by becoming an assistant in the Pulkowa Observatory, of which his father, Otto Struve, was director, and soon gave evidence of the powers that led to his call, in 1895, to the directorship of the

Königsberg Observatory, and to his succession to the directorship of the Berlin Observatory upon the retirement of Wilhelm Foerster in 1904. It was under his direction and largely upon his initiative that the new Berlin-Babelsberg Observatory—one of the best appointed in Europe—was built.

Struve began to observe the satellites of *Saturn* in 1883, and it is for his observations of these bodies and for his theoretical studies of their motions and of those of the satellites of *Uranus*, *Mars*, and *Neptune* that he is best known.

A sympathetic sketch of his life by Professor Courvoisier is printed in Number 5067 of the *Astronomische Nachrichten*.

Giovanni Celoria began his astronomical career as assistant in the Milan (di Brera) Observatory under Schiaparelli nearly sixty years ago and continued in his allegiance to that institution to the time of his death, serving as assistant astronomer, astronomer, and finally as director. He had to his credit a long list of papers dealing with measures and orbits of comets, minor planets, and double stars.

It is worthy of record here that Mr. James Hartness, of Springfield, Vermont, the designer of the Hartness Turret Telescope, and an enthusiastic student of astronomy, as well as a prominent engineer and manufacturer, has been elected governor of the state of Vermont.

To Double-Star Observers.—In accordance with the wishes of my friend, the late Professor Eric Doolittle, and my promise made to him in 1919, I have undertaken the completion of the Extension to Burnham's *General Catalogue of Double Stars* upon which he had been engaged since 1913 when Professor Burnham turned over to him the data he had collected. This arrangement has Professor Burnham's cordial approval.

The work should be published at the earliest practicable date and I have Director Campbell's assurance of such assistance on the part of the Lick Observatory as may be needed to complete the manuscript for the printer.

I respectfully request all double star observers to cooperate by sending me copies of their papers printed in the present year as well as of those which they publish later.

Mount Hamilton, California. ROBERT G. AITKEN.

The Adolfo Stahl Lectures in Astronomy.—The holiday season is at hand and our readers are doubtless giving thought to the selection of gifts for friends. We respectfully suggest that a copy of the *Adolfo Stahl Lectures* would be appreciated by any friend having an interest in astronomy.

The volume continues to meet with the commendation of readers and reviewers. As evidence, we refer to M. Jean Bosler's review in the *Revue générale des Sciences*, **31**, 225, 1920, and venture to quote a sentence or two from a personal letter recently received by one of the contributors to the volume.

"Shortly before I left the U. S. A. on my recent visit, I bought a copy of the *Adolfo Stahl Lectures* and I have just read [the lecture on] 'The Nebulae.' It was a revelation to me, and I realized how much out of date I have become during the last few years. . . . I find the *Adolfo Stahl Lectures* of the utmost value."

Application for copies should be addressed to Mr. D. S. Richardson, 709 Postal Telegraph Building, 22 Battery St., San Francisco, California.

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MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON SATURDAY, NOVEMBER 27, 1920, AT 2:00 P. M.

There were present President Moore and Directors Cushing, Black, Benfield, Einarsson, Costa and Richardson.

The following new members were elected:

To Life Membership
Mr. Henry C. Gibson, of Philadelphia, Penn.
To Active Membership
Mr. Charles E. Grunsky, of San Francisco, Cal.
Mr. J.Frank Lanning, of Pittsburgh, Penn.
Rev. Paul M. McDade, of Collins, Iowa.
Mr. R. G. Manifold, of Riverside, Cal.
Mr. S. W. McKee, of Los Angeles, Cal.
Mr. Albert F. Schroeder, of Cleveland, Ohio.
"Suroda"—Hydrographic Office, Tokyo, Japan.
Mr. John H. Darling, of Duluth, Minn.

A communication was read from Director Aitken, of the Publication Committee, inviting attention to the increased cost of printing and asking consideration by the Board of the general financial condition of the Society.

Discussion followed, during which it was shown by the Treasurer that the Society has sufficient funds on hand temporarily to continue present printing arrangements, and a resolution was passed instructing the Finance Committee to make an exhaustive examination of the Society's finances and report, with recommendations, at the annual meeting in January, 1921.

A resolution was passed, authorizing Director Costa, as a Committee of one, acting in conjunction with such other persons or members as he might call to his aid, to take up with the heirs of the late Joseph A. Donohoe the matter of so modifying the Comet Medal Endowment as to permit of a more liberal use of the Donohoe Comet Medal Fund. Director Costa was instructed to report at the next meeting.

A vote of thanks was extended to Mr. W. A. Clark, Jr., and Dr. Mars Baumgardt, of the Clark Observatory of Los Angeles, for the gift to the Society of a very large and handsome photograph of the Moon and a radium star map showing the constellation of *Orion*.

The President appointed the following committees:

Nomination of officers for the ensuing year—
Messrs. B. L. Hodghead, Chairman,
Allen H. Babcock,
Frank V. Cornish.

Auditing Committee—
Charles S. Cushing,
J. D. Galloway,
Miss Edith M. Allyne.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC TO AWARD THE BRUCE GOLD MEDAL FOR THE YEAR 1921, HELD IN THE ROOMS OF THE SOCIETY ON SATURDAY, NOVEMBER 27, 1920, AT 2:30 P. M.

There were present President Moore and Directors Cushing, Costa, Benfield, Black, Einarsson and Richardson.

The proxies of Directors Campbell and Aitken were held by President Moore. The proxy of Director Hale, in favor of Director Campbell, could not be utilized because of the absence of the latter.

Nominations were received from the Directors of the six co-operating observatories which, under the statutes of the Bruce award, act with the Board of Directors of the Society in making a selection. Careful consideration was given to the eleven distinguished names submitted, resulting in the unanimous selection of one whose name will be announced so soon as he shall signify his acceptance of the honor.

Adjourned.

D. S. RICHARDSON,
Secretary.

OFFICERS OF THE SOCIETY.

J. H. MOORE	*President*
BERNARD BENFIELD	*First Vice-President*
J. COSTA	*Second Vice-President*
A. L. BLACK	*Third Vice-President*
D. S. RICHARDSON	*Secretary and Treasurer*

Board of Directors—WM. H. CROCKER, C. S. CUSHING, D. S. RICHARDSON, J. COSTA, R. G. AITKEN, G. E. HALE, B. BENFIELD, W. W. CAMPBELL, A. L. BLACK, J. H. MOORE, STURLA EINARSSON.

Publication Committee—R. G. AITKEN, H. SHAPLEY, J. H. MOORE.
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Comet-Medal Committee—W. W. CAMPBELL, STURLA EINARSSON, H. M. JEFFERS.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

The library of the Society is now located in the Sutro Branch of the California State Library, at the corner of Sacramento and Webster Streets, San Francisco, where the books may be consulted or taken out by Members, subject to the regulations of the State Library.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication. R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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